The development of a risk management framework that integrates with the quality control and food safety management system of a catfish processing pilot plant

by

Carla Vernooy

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Study leader: Prof A.F van der Merwe

Co-study leader: Mrs. S Henning

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DECLARATION

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ABSTRACT

The following research describes the steps taken to create a method for Blue Karoo Trust (BKT), a company specialising in aquaculture and the processing of African sharptooth catfish (*Clarias gariepinus*), to identify risks at any stage during the catfish processing, and to determine the financial impact of the occurrence of such a risk. Finally, the method will recommend how the situation should be managed in order to control the risk.

The BKT catfish farming project is contributing to the development of the aquaculture sector of South Africa and succeeds in producing a sustainable, high-protein food source. The company strives to become Hazard Analysis and Critical Control Points (HACCP) and FSSC 22000 certified to ensure the production of safe food. A HACCP system has been developed for the production at the pilot plant, but it is yet to be implemented on the production line. The goal of the processing facility is to upgrade from a pilot to commercial scale plant once the production line becomes commercially viable and sustainable.

BKT, as an emerging company, is exposed to various types of risks. It was established that the company has no formal risk management system in place. The proposed risk management framework seeks to provide BKT with a method to identify risks in the production value chain that could affect the quality of the product, the production time, and the financial performance of the company.

A value chain in the form of a process flow diagram was created by making use of the production procedures prescribed by the quality and safety management systems of BKT. The process flow diagram was validated by comparing the actual activities on the production line to the official procedures, as stated in the HACCP plan. Additionally, a mass balance, time study, as well as a cost analysis, were conducted in order to complete the value chain of the processing line and to facilitate the quantification of risks. Furthermore, interviews were conducted with employees and supervisors to determine the factors inhibiting the workforce from implementing hygiene and food safety principles.

A sensitivity analysis was conducted to validate that the framework is able to identify, quantify, and control risk in the processing line. The outcome of the sensitivity analysis was validated by consulting with experts in the food production operations field.

Ultimately, a framework that is able to guide management of the catfish processing facility to identify, quantify and control risks in the processing line was developed and verified.

OPSOMMING

Hierdie navorsingstudie stel die stappe voor wat geneem is om vir Blue Karoo Trust (BKT), ‘n maatskappy wat betrokke is by akwakultuur en die verwerking van Afrikaanse skerptandbaber (*Clarias gariepinus),* ‘n metode te ontwikkel wat hul in staat sal stel om risiko’s tydens prosesseringsstappe te identifiseer en die finansiële uitwerking daarvan, te kwantifiseer. Die metode maak ook voorstelle hoe die risiko bepaal kan word en hoe om die negatiewe impak daarvan te minimeer.

Die akwakultuurprojek van BKT dra tans by tot die ontwikkeling van die akwakultuurindustrie van Suid Afrika en slaag daarin om ‘n volhoubare bron van hoë-proteïenvoedsel te vervaardig. Die maatskappy beoog om *Hazard Analysis and Critical Control Points* (HACCP) en FSSC 22000 gesertifiseer te wees en om op so ‘n manier te verseker dat hul voedsel produseer wat veilig is vir menslike verbruik. ‘n *HACCP* plan is reeds ontwikkel vir die proefaanleg se prosesseringslyn, maar word tans nie geïmplementeer nie. Die einddoel van die prosesseringsfasiliteit is om van proefaanlegskaal oor te skakel na kommersiële vervaardigingsskaal wanneer die produksielyn kommersieel lewensvatbaar en volhoubaar is.

BKT is ‘n opkomende besigheid en word dus blootgestel aan verskeie risiko’s. Dit was bevestig dat die besigheid geen formele risikobestuursisteem in plek het nie. Die voorgestelde risikobestuurraamwerk beoog om vir BKT ‘n metode te verskaf waarmee risiko’s in die produksiewaardeketting geïdentifiseer kan word. Meer spesifiek teiken dit risiko’s wat ‘n moontlike negatiewe impak op die kwaliteit van die produk sal hê, die produksietyd sal beïnvloed en uiteindelik die finansiële toestand van die maatskappy sal beïnvloed.

‘n Waardeketting van die produksielyn is ontwikkel in die vorm van ‘n prosesvloeidiagram deur gebruik te maak van die voorgestelde produksieprosedures in die *HACCP* plan van die produksielyn. Die prosesvloeidiagram was versterk deur die ware produksieproses waar te neem en te bepaal of die vloeidiagram ooreenstem met die waargenome prosesse. ‘n Massabalans, ‘n tydstudie en ‘n koste-analise was ook uitgevoer op die produksielyn om die opgestelde waardeketting aan te vul en om risiko kwantifisering toe te laat. Verder was onderhoude met produksielyn-werkers en -opsigters gevoer om risiko’s ten opsigte van die implementering van voedsel veiligheidssisteme te identifiseer.

‘n Sensitiwiteitsanalise was uitgevoer op die waardekettingmodel om te verseker dat the raamwerk in staat is om risiko’s in die produksielyn te kan identifiseer, te kwantifiseer en te beheer. Die uitkomste van die sensitiwiteitsanalise was bekragtig deur operasionele deskundiges in die industrie te raadpleeg.

‘n Raamwerk was uiteindelik opgestel vir BKT wat die bestuur in staat sal stel om risiko’s te identifiseer en te beheer op die produksielyn.

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LIST OF ACRONYMS AND ABBREVIATIONS

BTK	Blue Karoo Trust
CSAP	Camdeboo Satellite Aquaculture Project
CPUT	Cape Peninsula University of Technology
GMP	Good Manufacturing Practices
FSFC	Foundation of Food Safety Certification
GFSI	Global Food Safety Initiative
ISO	International Organisation for Standardisation
HACCP	Hazard Analysis and Critical Control Point
WCADI	Western Cape Aquaculture Development Initiative
FAO	Food and Agriculture Organisation
WHO	The World Health Organisation
FSMS	Food Safety Management System
PRP	Prerequisite Programme
GHP	Good Hygiene Practices
GLOBALG.A.P.	Global Good Agricultural Practices
FSSC	Food Safety System Certification
GFSI	Global Food Safety Initiative
PAS	Publicly Available Specification
PBD	Process Block Diagram
PFD	Process Flow Diagram
ILO	International Labour Office
OT	Observed Time
NT	Normal Time
R	Performance Rating
ST	Standard Time
LB	Line Balancing
ABC	Activity Based Costing
SPSS	Statistical Package for the Social Sciences
HTVP	Hydrated Textured Vegetable Protein
GFST	Global Food Safety Training
NRCS	National Regulator for Compulsory Specifications
AFTS	AgriFood Technology Station
SD	Standard Deviation
COGS	Cost of Goods Sold

1. INTRODUCTION

1.1 Introduction to Blue Karoo Trust

The African sharptooth catfish (*Clarias gariepinus*) processing operation of Blue Karoo Trust (BKT) is the main subject of this study. The Camdeboo Satellite Aquaculture Project (CSAP) involves the training of unemployed people from rural areas in the Eastern Cape such as Graaff-Reinet, Aberdeen, and Nieu-Bethesda. The training includes aquaculture farming principles as well as food safety and hygiene practices. The trained employees farm and harvest the African sharptooth catfish (*Clarias gariepinus*) at the aquaculture facility, after which it is processed into an affordable food product for human consumption.

BKT sought out a market-driven business opportunity by identifying underutilised water resources in the Eastern Cape area as well as unemployed, and frequently uneducated, rural people who are available to work (De La Harpe, 2015). BKT also identified the global food security problem concerning the state of the world's catch fisheries and the fact that many marine species are currently being exploited (De La Harpe, 2015). Fish farming presents a viable and sustainable solution to address both the unemployment rate in the rural areas of Eastern Cape and the decreasing marine fish supply.

The CSAP was initiated in 2006, and in 2013, a small-scale fish farming facility was established on the Graaff-Reinet farm, together with the aquaculture training facility. Construction of the processing facility began in 2015 and is scheduled to be finished by 2017. However, presently the fish is cleaned, eviscerated, filleted and minced at the pilot plant, which is based at the educational food factory of Cape Peninsula University of Technology (CPUT). The minced fish is transported in crates (between 0^0C and 4^0C) to Le Cap Foods in Stellenbosch where packaging and heat processing takes place. The production line, from receiving the fish to heat processing, will upgrade to a commercial production scale plant when the construction in Graaff-Reinet is complete. However, before the upgrade can take place, the production line has to be commercially viable and sustainable.

A maximum of 10 ton of fish is harvested at the farm every month whilst contract packing takes place (De La Harpe, 2015), however, the harvested amount greatly depends on the availability of the pilot plant and the processing capacity at Le Cap foods. BKT has plans for product variations such as fish mince with a variety of sauce, as well as fish mince with maize meal or vegetable protein. Their largest customer specialises in bulk catering, therefore the product is packaged in 2 kg retort pouches. However, BKT aims to make the product appealing to retail outlets as well by manufacturing a 200 g pouch. Furthermore, pet food is produced as a by-product from the head, jaws, gills, and tail fin of the fish. This product is still in the developing stage, but pet food manufacturers have already shown interest in the product. In addition, the gut and blood will be processed into fertiliser once the Graaff-Reinet facility is in operation. BKT aims to utilise as much as possible from the whole fish and to minimise waste.

The operation of such a large project is associated with considerable financial risk and BKT's largest obstacle at the moment is to obtain financial support to implement the production operations at a commercially viable scale (De La Harpe, 2015). In order to minimise financial loss in the future, it is important that BKT identify all possible operational risks that will potentially influence the sustainability of the company. An effective risk management system will increase the probability of the CSAP success and is likely to reduce the possibility of failure in the company. Another major challenge BKT faces is to produce a product of consistent quality that adheres to food safety standards, due to the fact that a large portion of their employees have never been part of a workforce, and have never worked with food in a factory (De La Harpe, 2015). The implementation and continuous monitoring, as well as verification of quality control and food safety management systems in the catfish-processing factory, is therefore critical.

The ultimate food safety goal of the BKT African sharptooth catfish (*Clarias gariepinus*) processing facility is to become FSSC 22000 certified - a certificate issued by the Foundation of Food Safety Certification (FSFC). This certificate is desired because its safety management framework is based on the ISO 22000 standards, issued by the International Organization for Standardization (ISO) and is approved by the Global Food Safety Initiative (GFSI). The first step towards this goal is to develop Good Manufacturing Practices (GMPs) and to become Hazard Analysis and Critical Control Points (HACCP) compliant. GMPs have been established and implemented in the CPUT-based pilot plant and at Le Cap foods, and an initial HACCP plan has been developed for both institutions. The HACCP team at the pilot plant is in the process of implementing the food safety system. However, a full HACCP plan for the operations in Graaff-Reinet is still undergoing development.

1.2 Rationale of the Study

The rationale of this study was to identify risks on the production line of the CPUT based pilot plant and at Le Cap Foods, as the identification and control of risk in the pilot plant will facilitate the production of fish mince on a commercial scale. The three main constraints identified in the Camdeboo Satellite Aquaculture Project are time and quality, which in turn are related to money. Events in the pilot plant of the catfish processing facility that may push the boundaries of these constraints must be identified as risks and should be controlled accordingly. A verified risk management framework that is specific to BKT's processes will enable the company to manage risks associated with food quality, processing time and money. The risk management system will in effect decrease the total monetary risk of BKT and will assist the company with producing a sustainable, high-quality product.

1.3 Research Problem Statement

The preliminary investigation suggests that the catfish processing facility of BKT does not have a risk management framework in place, which leads to the company being unprotected against the occurrence of spontaneous events that may threaten the achievement of company goals regarding time, money, and food quality.

The problem statement leads to the following research question that will be addressed by the study:

- Is the proposed risk management framework able to identify and control risks in the catfish processing facility of BKT?

1.4 Research Objectives

The aim of this study was to develop a risk management framework for BKT that integrates with the quality and safety management system and that enables the identification and control of risks in the catfish processing plant. This framework is aimed at assisting management to achieve company goals with regard to food safety, quality, time and money.

In order to achieve the above-mentioned aim and address the research question, the following objectives form the basis of this study:

1. To investigate appropriate focus areas of risk management:
   1.1. To investigate various risk management frameworks.
   1.2. To investigate risk management techniques in the food industry.

2. To identify risks and to suggest appropriate control strategies.

3. To forecast the sensitivity of the framework by applying possible risks scenarios.
   3.1. Test the framework with appropriate risk scenarios in the current operations of the pilot plant.
   3.2. Show that the proposed risk management framework can be utilised by BKT to achieve company goals in the full-scale plant.

1.5 Significance of the Study

Many organisations in South Africa, such as the Department of Agriculture, Forestry and Fisheries, the Western Cape Aquaculture Development Initiative (WCADI) and the Tilapia Aquaculture Association of South Africa are investing in various aquaculture projects in order to address the problem of unemployment in

South Africa. WCADI works closely with Operation Phakisa and fully supports its projects (WCADI, 2012). Operation Phakisa is an initiative of the South African government aimed at addressing poverty, crime, and unemployment by exploiting the oceans and the naturally available resources in the country. Operation Phakisa had success with abalone, oyster and mussel farms on the coast of the Western Cape and contributed to this province being the leading Aquaculture farming province in South Africa (WCADI, 2012).

It is clear that the South African government is supporting aquaculture projects, with the conviction that it will assist in alleviating poverty and unemployment in the country. The Camdeboo Satellite Aquaculture Project initiated by BKT has the support of the government since the project is adding value to the lives of numerous unemployed South Africans, thereby stimulating the South African economy. There is a global movement towards aquaculture, and South Africa has the potential to become a major player in this field. However, in order to ensure the sustainability of the catfish processing operation, it is necessary to forecast and manage the constraints of such a project. A risk management framework will enable BKT to control the risks associated with the catfish processing operation and will in effect increase their chance of success. This research study is, therefore, part of a larger, national aquaculture study, and will ultimately contribute to the development of aquaculture in the Eastern Cape, as well as in South Africa as a whole.

1.6 Scope of the Study

The risk management framework was specifically developed for the operations in the CPUT-based catfish processing pilot plant and at Le Cap Foods in Stellenbosch. The CPUT-based pilot plant and the processing operation at Le Cap Foods is only available for a limited time, as it will be moving to Graaff-Reinet in 2017. It was, therefore, crucial to conduct all experiments before the obsolescence of the pilot plant. Another time constraint is the fact that processing at the pilot plant only occurred once or twice a month. Furthermore, the aim was to develop the risk management framework for the pilot plant while keeping the full-scale plant in mind. The risk management framework is, therefore, applicable to the commercial scale plant in Graaff-Reinet, taking into consideration that production volumes will increase significantly.

Additionally, the operations of the catfish processing plant were studied extensively, and the framework was solely based on the information obtained from the study. Evidently, it is assumed that the risk management framework, in its original form, is not applicable to the production line of any other food manufacturing facility. The uniqueness of the catfish processing line prohibited the researcher from validating the risk management framework other food processing lines. The validation therefore took the form of interviews with experts in the field. Nevertheless, with further research, the framework can possible be altered to fit the operations of a food manufacturing facility with similar production processes.

As previously mentioned, the study was focussed on production processes that took place at the CPUT-based pilot plant and at Le Cap Foods. The focus of this study started at the point where the fresh and whole fish was received at CPUT from the farm, until the point where the fish was taken out of the retort at Le Cap Foods. This research study did not include the aquaculture operations on the farm at Graaff-Reinet, which included the breeding and the feeding of the fish from fry to 1 kg in size, as well as the harvesting process. In addition, due to the fact that the study solely focussed on the internal processes of the catfish processing pilot plant, the risk management framework was specifically developed for internal risks of the facility.

1.7 Thesis Outline

The following outline will lay the basis for this thesis.

The first chapter will discuss the background and the significance of this study. The company on which the case study was based, Blue Karoo Trust, will be introduced. Furthermore, the problem statement, as well as the research objectives that will be achieved through this study, will be discussed. The aim of the first chapter is to provide the reader with an introduction to the rationale of the study.

The second chapter will contain the Literature Study. This covers the study of the literature on relevant topics related to this research. These topics include the status of the aquaculture industry on the national and international levels, the design of food processes, quality control, and Food Safety Management Systems in the food industry, risk management, risk management frameworks, and finally, HACCP implementation and change management strategies. The literature study will provide a foundation for the Methodology chapter and for the Results and Discussion chapter. In addition, the Literature Review chapter focusses on achieving the first research objective of this study.

The third chapter will discuss the Research Design and Methodology applied in this study. Firstly, there will be a discussion on the ethical aspects that were considered before the research was conducted. The following section introduces the research design employed in this study and the rationale behind the decision. The discussion aims to provide the reader with an idea of what can be expected from the methodology. The specific research methods used to obtain qualitative as well as quantitative information for this study is then discussed in detail. The applicability of each research method with regard to achieving the research objectives will also be discussed. The research methodology outlines the methods by which the second research objective of this study will be obtained. This chapter ends with a discussion on the statistical approach used for data analysis.

The fourth chapter, which is the Results and Discussion chapter, presents the results obtained from the research methods discussed in the previous chapter. The Results and Discussion chapter aims to present the risks identified in the catfish processing pilot plant as well as the control strategies proposed for each, in effect, addressing the second research objective of this study. The chapter will also present a sensitivity analysis done on the value chain model developed for the catfish processing pilot plant. The sensitivity analysis will ultimately address the third research objective of this study.

The final chapter of this thesis provides Conclusions and Recommendations. This chapter aims to highlight the most significant findings and discusses the validity of the risk management framework as well as recommendations for conducting future studies.

1.8 Summary

In this chapter, an introduction to the company, Blue Karoo Trust, was provided, and the significance of the Camdeboo Satellite Aquaculture Project, initiated by Blue Karoo Trust, was discussed with regard to the development of South Africa's aquaculture sector. The company's need for a risk management framework was identified and the problem statement led to the formation of three major research objectives. The research objectives include the investigation of risk management frameworks, the identification of risks and the proposal of corresponding control strategies, and finally, testing the sensitivity of the framework by applying appropriate risk scenarios.

2. LITERATURE STUDY

2.1 Introduction

A literature review was conducted to determine the degree of research that has been done on the topic. The information obtained from the literature review was used to support the Methodology section, as well as the Results and Discussion section in this thesis. This chapter is structured according to the main themes of the study.

2.2 The Aquaculture Industry

The status of the South African aquaculture industry is important with regard to the background of this study, as it is necessary to have an indication of the environment in which Blue Karoo Trust (BKT) has introduced their catfish farming project. The following sections will focus on the development of the aquaculture industry on a global, as well as a local scale. Lastly, the status of the catfish industry in South Africa will also be discussed.

2.2.1 International

It is asserted in literature that the global production of capture fisheries is stagnating due to overfishing and a constant increase in global population (Shipton & Britz, 2007; Srinivasan *et al.*, 2010; Ottinger *et al.*, 2016). Fisheries are depleting marine resources, thereby placing the availability of a critical food source at risk and damaging the world economy in the long term (Srinivasan *et al.*, 2010). Initiatives have been undertaken to uncover alternative resources for fish, which have led to the development of the aquaculture industry. For the past two decades, global production of aquaculture has grown at an average rate of 8.6% per year (FAO, 2014) which exceeds that of poultry (4.9%), pig (2.9%), sheep (1.8%), cattle (1.4%) and other fishery (1.2%) productions (Natale *et al.*, 2013; Troell *et al.*, 2014). Aquaculture productions are expected to grow at 4.5% per annum for the next two decades (Shipton & Britz, 2007). It can be seen that the growth rate of the aquaculture industry is following an adoption curve and is currently in the rapid growth phase (Bostock *et al.*, 2010). It is estimated that the total quantity of aquaculture production, which was 72.8 million tonnes in 2014, will be twice as much by 2030 (FAO, 2014).

Currently, the aquaculture industry is producing 50% of the global fish supply, of which China is the largest producer (Bostock *et al.*, 2010; FAO, 2014). This is mainly due to the population and economic growth in Asia, as well as their undemanding environmental regulations (Bostock *et al.*, 2010). In contrast, the development rate of the aquaculture industry in Europe and North America has stagnated due to heavy environmental regulatory requirements (Bostock *et al.*, 2010). Although aquaculture may have many benefits, operating an aquaculture facility places strain on the surrounding environment by using natural resources such as water, energy, and feed (Bostock *et al.*, 2010). Freshwater fish farming operations generally take water from a pond nearby and then allow the effluent of the farm to flow out into the environment again. Water is therefore placed back into the environment, but usually, the quality of the water is reduced (Bostock *et al.*, 2010). Additionally, the use of fish meal and fish oil as feed for some aquaculture species is also an environmental issue and is unsustainable, as the aquaculture industry is responsible for taking a majority of the wild-caught small pelagic fish produce as feed (Natale *et al.*, 2013).

Furthermore, other critical factors influencing the development of aquaculture in a country include market demand, infrastructure, environmental conditions, technical capabilities, investment opportunities and human resource development (Muir & Young, 1998). All of these factors pose a risk to the success of an aquaculture operation. A technical paper has been published by the Food and Agricultural Organisation of the United Nations (FAO) (2008) in an attempt to educate individuals and companies on risk analysis procedures that assist with minimising risk in the company and promotes sustainability. In the past, the aquaculture industry has generally applied risk analysis to environmental risks (Arthur *et al*., 2009). The industry has failed to use risk analysis for biological, financial and social risks up to this point (Arthur *et al*., 2009), therefore further research is required on this topic.

2.2.2 National

The newly formed aquaculture sector in South Africa focussed on producing high-value products in the past due to the high input costs of aquaculture operations (Shipton & Britz, 2007; WESGRO, 2012). Today, since abalone is considered a high-value product, it is still the largest contributor to the total production of aquaculture in South Africa (WESGRO, 2012). According to Shipton and Britz (2007), South Africa has major fish farming potential due to the country's favourable environmental conditions. However, South Africa is not meeting its full potential due to lack of access to suitable farming locations, high capital costs and market barriers (Shipton & Britz, 2007). Shipton and Britz (2007) state that aquaculture development is essential in South Africa as the local marine fish supply is declining, thereby creating a gap in the market. Unfortunately, establishing a full-scale fish farming operation takes a few years, which could result in the gap being filled by imported farmed fish products.

Potential investors of the South African aquaculture industry are generally discouraged by rezoning requests, tedious requirements for obtaining permits as well as demanding environmental regulations (Shipton & Britz, 2007). It is necessary for the government to declare a piece of land suitable before any aquaculture operations may commence and this often obstructs development. Another major constraint for the development of aquaculture in South Africa, as identified by Shipton and Britz (2007), is a lack of aquaculture training programmes, and thus aquaculture farming skills. Tertiary courses focussed on aquaculture are well established at the Universities of Stellenbosch, Rhodes, and Limpopo, however, no practical aquaculture courses are offered by any Universities of Technology in the country (Shipton & Britz, 2007). Furthermore, there are a few initiatives focussed on providing basic aquaculture training, such as the Transport-SETA that is funding abalone culture training in Port Nolloth. The lack of basic aquaculture training has led to the formation of a knowledge and organisational gap in the aquaculture industry. Senior employees will have a tertiary degree, not necessarily focussed on aquaculture, and lower level employees will only have a matric certificate, as no basic training courses are available. This gap results in less efficient employees and thus lower productivity. More aquaculture training facilities and opportunities are required to stimulate the development of aquaculture in South Africa.

2.2.3 Catfish Farming in South Africa

The catfish farming industry in South Africa was established in the early 1980's and developed so rapidly that over a 1000 tons of African sharptooth catfish (*Clarias gariepinus*) were produced at the end of the decade (Shipton & Britz, 2007). After 1993 production numbers declined as businesses closed down due to marketing constraints (Hoffman *et al.*, 2000; Shipton & Britz, 2007). After the year 2000, investors tried to re-establish the catfish production sector by promoting potential catfish export opportunities to Thailand (Shipton & Britz, 2007). Unfortunately, economic factors in South Africa did not allow profitable exporting at that time, and the catfish farming projects failed again (Shipton & Britz, 2007).

The technology in South Africa is well developed for catfish farming and climate conditions make South Africa a favourable farming location for the African sharptooth catfish (*Clarias gariepinus*) (Shipton & Britz, 2007). The major constraint of catfish farming in South Africa is, in fact, the market barrier (Shipton & Britz, 2007). The African sharptooth catfish (*Clarias gariepinus*) is specifically poorly accepted by consumers due to the reddish appearance of its fillets that is wrongly perceived as blood (Shipton & Britz, 2007). In addition, South Africa is not considered a fish-eating nation, thus also contributing to the poor market response (Shipton & Britz, 2007). Immigrants in South Africa from Nigeria and Congo are potential consumers of the catfish, as the fish is seen as a traditional dish in those countries; however, this market is too small to support the entire catfish industry (Shipton & Britz, 2007). Therefore, the challenge of the African sharptooth catfish (*Clarias gariepinus*) farming industry is to develop an appealing and affordable product.

It is clear from the above sections that the operation of an aquaculture project, especially in South Africa, involve many risks. Risk management should be implemented in these projects to facilitate decision-making and to ensure sustainability. However, before risk management can be implemented in a manufacturing facility, the process design within the factory must be studied and understood.

2.3 Food Process Design

The risk involved in food production can only be managed if all aspects of the production process are understood. The design of food manufacturing processes in a facility must be studied in order to determine the process requirements and the constraints of the system, which is frequently attributed to time, cost or quality. The time and cost considerations of a production system will be discussed in the following section, however, the quality aspect will be discussed in a separate section due to its importance in the food industry.

2.3.1 Process Flow

The development of a process flow diagram, which can be described as a visual representation of the relationship among processes, is common in numerous fields of engineering (Clark, 2009:27). According to Clark (2009:27), a process flow diagram is used in process engineering to display the movement of materials and the quantities thereof from one operation to another. In addition, the development of a process flow diagram is one of the first tasks to be completed before a Hazard Analysis and Critical Control Point (HACCP) study is conducted (Mortimore, 2001), and is, therefore, also relevant to the food industry.

The development of a flow diagram allows management to consider the possibility of other materials to enter the process (Clark, 2009:27). This is important to consider in a food manufacturing facility, as any foreign material to enter the production line is considered a physical hazard. A flow diagram also considers the movement of materials and the quantities thereof, and may indicate where the most waste is generated (Clark, 2009:27). Furthermore, the development of a process flow diagram may emphasise the type and the amount of resources needed to conduct a specific operation (Clark, 2009:27).

During the creation of the process flow diagram, which is an iterative process in the initial stages of a company, it is important to create and keep an ideal process flow diagram for the factory operations (Clark, 2009:29). This document is regarded as the base for the operation and can be used to identify and measure deviations (Clark, 2009:29). In a food manufacturing company, the sequence of operations developed by the HACCP team may be regarded as the base flow diagram as it forms part of the Food Safety Management System (FSMS) and adheres to legislation.

2.3.2 Material Flow Analysis

Material flow analysis can be defined as a systematic approach towards assessing the flow of goods and substances within a system that is defined by specific time and space (Brunner & Rechberger, 2004:3). A material flow analysis is governed by the laws of material conservation, thus the results of such an analysis can be controlled by conducting a simple material mass balance. According to Clark (2009:27), material mass balance calculations are based on the concept that the amount of material that goes into the system, comes out of the system, in one form or another. If there is an imbalance between inputs and outputs, some material flows have not been considered or there is an error in the flow determination (Brunner & Rechberger, 2004:59).

The material mass balance aspect of material flow analysis allows it to act as a decision-support tool in resource management and waste control (Brunner & Rechberger, 2004:3). The practice of balancing material input and product output allows for the identification of waste-producing processes (Brunner & Rechberger, 2004) and therefore aids in maximising product yield. Furthermore, the control of processes in a food manufacturing facility, and the optimisation thereof can be achieved by conducting a material flow analysis (Maroulis & Saravacos, 2003:31).

The material flow analysis comprises of several steps. It is important to define the problem and goals of the analysis before starting the process (Brunner & Rechberger, 2004:53). Once the goals have been defined, the materials, as well as the system to be analysed, must be selected (Brunner & Rechberger, 2004:53). In material flow analysis, materials can be defined as either substances or goods. Substances can be defined as a unit consisting out of a single type of matter, whereas goods are defined as a unit consisting of a combination of various substances bearing economic value (Brunner & Rechberger, 2004:3). Thus, the material choice will depend on the purpose of the analysis and the type of application. Furthermore, the system in which a material flow analysis is conducted will consist out of various processes. Processes are defined by their inputs and outputs and are linked to other processes by means of material flows (mass per time unit) (Brunner & Rechberger, 2004:4). The type of system selected will generally depend on the scope of the analysis and system boundaries must be defined by space and time (Brunner & Rechberger, 2004:56). According to Brunner and Rechberger (2004:56), the chosen system must be as small and constant as possible without excluding any important processes. The next step in a material flow analysis involves the determination of mass flows. Data for mass flows can either be obtained from databases or can be measured on the site of the system, depending on the nature of the study and the availability of resources (Brunner & Rechberger, 2004:59). Data acquisition must be made automated, if possible, and standard acquisition procedures must be established (Brunner & Rechberger, 2004:65).

An important consideration in material flow analysis is the format in which the results are presented. The aim is to present the information in a clear and functional way, so that technical experts and managers, as well as relevant stakeholders, can understand the findings of the study (Brunner & Rechberger, 2004:64).

2.3.3 Time Study

Time is a common restriction in any project and is usually related to the cost and quality of a product (Perminova *et al.*, 2008). Improper management of time can place a company at risk. More specifically, failing to develop operational time standards can lead to higher production costs, conflict between personnel and can eventually contribute to business failure (Freivalds & Niebel, 2009:406). In order to avoid the risk, a time study must be conducted and company-specific time standards must be developed.

All job requirements and specifications must be defined and standardised before a time standard can be developed for a task (Freivalds & Niebel, 2009:406). Managers standardise procedures by evaluating and adjusting current job activities until a final procedure is accepted (Freivalds & Niebel, 2009:406). The procedures may be standardised together with the development of a process flow diagram. It is then the responsibility of the managers and supervisors to verify that the standardised procedures are carried out correctly (Freivalds & Niebel, 2009:407) or alternatively to verify the process flow diagram. According to Freivalds and Niebel (2009:407), the time study analyst should also determine if the job is carried out correctly while recording the time by awarding a performance rating to the operator.

A time study form, which should include the steps of the production process, is used to conduct a time study. The observed time (OT) is indicated on the form, as well as a performance rating for the operator in each step of the production line (Freivalds & Niebel, 2009:411). Each element in the operation is observed for a few cycles in order to get an average for the OT. The time it takes to complete a job in the processing line will largely depend on the skill and effort of the operator (Freivalds & Niebel, 2009:424). The performance of the operator must be rated against the performance of a qualified operator working at a standard pace (Freivalds & Niebel, 2009:425). The Normal Time (NT) rating is obtained by multiplying the performance rating with the OT reading (Freivalds & Niebel, 2009:425). The normal time reading is the time it will take a qualified operator to complete the same amount of work as the observed operator (Freivalds & Niebel, 2009:425).

Furthermore, time allowances must be incorporated into the working time of an operator, as all employees are entitled to breaks throughout the workday (Freivalds & Niebel, 2009:425). Allowances are also considered to compensate for lost time during production (Freivalds & Niebel, 2009:452). Allowances can be categorised into three classes. The first being personal breaks, which include bathroom breaks (Freivalds & Niebel, 2009:425). Personal breaks are necessary to ensure that the employee is able to work at a standard pace. According to Freivalds and Niebel (2009:454), a 5 % allowance time for personal breaks is adequate for employees in a manufacturing type of environment.

The second class includes allowances given to avoid fatigue (Freivalds & Niebel, 2009:425). In order to manage basic fatigue effectively in the working environment, a percentage allowance should be allocated so that employees may recover from effort expended to carry out the work (Freivalds & Niebel, 2009:454). The International Labour Office (ILO) of Switzerland (1992:332) states that an adequate allowance to recover from basic fatigue is 4%. The 4% allowance is sufficient for a person that is doing light work while sitting. However, allowances must also be considered for variable fatigue (Freivalds & Niebel, 2009:455). This type of fatigue will hinder the operator from working at a standard pace. The main factors contributing to variable fatigue is the nature of work, the condition of the working environment, and the overall health condition of the employee

(Freivalds & Niebel, 2009:455). Variable fatigue can be categorised into physical strain, mental strain, and strain caused by the environmental conditions (ILO, 1992:490-497). A table is provided by the ILO (1992:491-498) in which guidelines for allowance factors are given for each of the these factors (Freivalds & Niebel, 2009:455).

Finally, the third class includes spontaneous delays, for instance, the breakdown of machinery (Freivalds & Niebel, 2009:425). Unavoidable delays include interruptions from supervisors or shift managers, as well as irregularities with equipment or incoming materials. Unavoidable delays also include interference delays where an operator is assigned to more than one machine (Freivalds & Niebel, 2009:466). Avoidable delays are generally not given any allowances, as these type of delays are caused by the ineffectiveness of staff members (Freivalds & Niebel, 2009:467).

The total allowance needed can be computed by obtaining the sum of the allowances for personal needs, basic fatigue, variable needs, unavoidable delays and extra allowances. The sum of the time allowances is added to the NT in order to obtain a Standard Time (ST) for each production step (Freivalds & Niebel, 2009:425). The ST rating can be defined as the time it takes a qualified operator, working at a normal pace with average effort, to complete a specific job (Freivalds & Niebel, 2009:425). Usually, the allowance is stated as a fraction of the normal time, otherwise, it can also be stated as a fraction of the workday (Freivalds & Niebel, 2009:426). The ST ratings can then be used as a reference to evaluate a work cycle or the performance of operators.

2.3.4 Lean Production

Lean production systems are governed by principles that reduce waste and inefficiencies along a production line and across the value chain of a product. More specifically, the four principles of lean manufacturing include identifying value from the customer’s point of view, mapping the value stream to identify non-value added activities, creating a continuous flow of product through the value chain by eliminating barriers, and finally, to let the value flow at the demand pull of the customer (Simons & Zokaei, 2005).

Line balancing (LB) is a concept that is regularly discussed together with lean manufacturing, as it also focusses on reducing waste, but specifically by eliminating waiting times and unnecessary processes. According to literature (Simons & Zokaei, 2005; Ongkunaruk & Wongsatit, 2014; Chueprasert & Ongkunaruk, 2015), LB has been applied in various food industries in an attempt to increase the productivity of the associated companies. Specific data regarding the production line is needed before LB can be conducted. The required information includes the sequence of the processing tasks (usually displayed in the form of a precedence network), the task times of each and finally, the cycle time, or alternatively, the number of workstations (Sivasankaran & Shahabudeen, 2014).

The cycle time of a food production line is determined by the task in the production line that takes the longest to complete (Sivasankaran & Shahabudeen, 2014). Evidently, once the bottleneck of the operation is identified, the cycle time of the production line can be determined. The cycle time of a food processing facility is influenced by the working speed of employees, machine speed and the speed of the conveyor (Chueprasert & Ongkunaruk, 2015). Long cycle times can influence the short term profits of a company, can lead to the accumulation of intermediate products and, especially in a food factory, increase the risk of product contamination or deterioration (Chen, 2013). Line Balancing addresses long cycle times by minimising workstations and by balancing the workload, thereby decreasing idle time and maximising productivity (Sivasankaran & Shahabudeen, 2014; Chueprasert & Ongkunaruk, 2015).

The takt-time of a production line is also regularly applied in line balancing or lean production systems. The takt-time technique successfully coordinates the production rate of the facility with the customer demand by obtaining a production time per unit (Simons & Zokaei, 2005). Evidently, if the production line produces a single product in less time than the takt-time, over-production occurs. Over-production leads to the consumption of resources that are not directly related to the production of finished goods (Simons & Zokaei, 2005) and inherently poses increased financial risk. The financial risk can therefore be reduced if the production line adheres to the takt-time of the operation. Operating to a takt-time also allows the employees at each workstation to operate at a constant rate, which is a valuable result in terms of line balancing.

According to Sivasankaran and Shahabudeen (2014), the line balancing of a single model production line can be solved by methods such as mathematical models, heuristics and optimum seeking algorithms. Although some of these methods have high success rates, companies generally struggle to implement it into their own operations (Falkenauer, 2005). This is due to the fact that most LB tools are based on theoretical circumstances rather than actual problems experienced by operations (Falkenauer, 2005). Therefore, Falkenauer (2005) suggests that if productivity is not a problem, the objective must be to equalise the workload across the production line. For instance, LB tools usually focus on designing a production line that is still to be constructed, whereas most current situations involve developed production lines (Falkenauer, 2005). Therefore, these companies rather seek a re-balancing of their lines. Furthermore, LB tools may suggest the elimination of some workstations, which is not practical in all circumstances. In addition, Falkenauer (2005) states that the classic LB problem usually sets the objective of minimising the total cycle time of the production line. However, if the facility is currently meeting its production target, decreasing the cycle time will only result in more idle time.

2.3.5 Value Chain Modelling

The original definition of a value chain describes it as being a sequential collection of primary and secondary activities performed by a company with the aim to convert raw materials and other inputs, into a value-added product that can be sold to a customer (Porter, 1980). A value chain analysis is able to allocate internal resources in an optimal manner, reduce waste and is able to improve the company's performance by identifying improvement opportunities and facilitating product management decisions (Chen *et al*., 2013).

An important concept in value chain analysis is that a product increases with value as it flows down the production line (Goodwin *et al.*, 2015:352). A profit is made once the created value exceeds that of the input cost. It is, therefore, in the best interest of the company to identify its internal activities that provide a competitive advantage (Hergert & Morris, 1989). These activities can be identified once the monetary value of a production activity is added to the product (Hergert & Morris, 1989). The economic value added can be determined by estimating the perceived value of the product in that production step. The perceived value of an activity can be defined as the price a customer is willing to pay for the product at each stage of processing (Hergert & Morris, 1989). However, if the specific intermediate product has no demand, and thus no economic value, the value addition of that activity must be substituted by an activity cost (Hergert & Morris, 1989).

Activity costs can be determined by means of a cost accounting system. According to Škoda *et al*. (2014), there are three cost accounting systems that are particularly important. The first system is known as the Direct Costing system. This system is a simple technique as only direct costs are considered when determining the cost of an operation (Škoda *et al*., 2014). This technique may be useful for companies that have small overhead costs. The second is known as the Traditional Absorption Costing system, and the third, the Activity Based Costing (ABC) system (Škoda *et al*., 2014). Both of these systems include overhead costs when determining product or activity costs. Overhead or indirect costs are included by applying cost drivers to the accounting data (Škoda *et al*., 2014).

The ABC system can be defined as a costing method that identifies the value-added activities in a production system, and allocates activity costs, together with resource consumption, to all products produced by the company, in accordance with their actual consumption (Ozkan & Karaibrahimoglu, 2013; Dwivedi & Chakraborty, 2014). The basic concept is that products consume activities, and activities require resources (Chen *et al*., 2013). ABC has received much attention in the past few decades because of its logical approach towards incorporating overhead costs into product or activity costs (Dwivedi & Chakraborty, 2014; Škoda *et al*., 2014). However, ABC fails to incorporate capital cost, investment risk, and cash flow factors and in effect may cause small companies to be under-evaluated (Roztocki & Lascola, 1999). Nevertheless, ABC is used as a tactical and strategic decision-making tool, as it is able to provide management with general cost accounting information (Dwivedi & Chakraborty, 2014).

Furthermore, literature suggests that ABC has become especially useful in the food manufacturing industry (Setala & Gunasekaran, 1996; Annaraud *et al*., 2008; Dwivedi & Chakraborty, 2014; Mogaji *et al.*, 2014; Koutouzidou *et al*., 2015). Koutouzidou *et al*. (2015) suggested that the ABC system provides the right amount of flexibility needed to calculate the unit cost of a food item accurately during production. In addition, Setala and Gunasekaran (1996) conducted a study that indicated the relevance of the ABC system to fish processing operations.

The development of an ABC model firstly requires that the cost object is identified (Annaraud *et al*., 2008). All production activities related to the cost object must be categorised as either value added or non-value added activities (Koutouzidou *et al*., 2015). Activities can be categorised into different activity levels. Four activity levels exist, namely the unit-level, batch-level, product-level and finally, the facility sustaining-level (Annaraud *et al*., 2008). Once these activities are identified, the amount and type of resources required to perform the activity must be allocated to each (Annaraud *et al*., 2008; Koutouzidou *et al*., 2015). These resources are also known as the elements of cost (Cokins & Lawson, 2006). The second step of developing an ABC model involves the identification of cost drivers that are associated with each individual activity (Koutouzidou *et al*., 2015). Cost drivers can be defined as the output measure of an activity, for instance, the number of labour hours needed (Annaraud *et al*., 2008). In the third step, a cost rate per cost driver is established, and finally, the activity costs are assigned to the designated products (Koutouzidou *et al*., 2015).

Furthermore, the elements of costs involved in a cost accounting system of a food manufacturing facility include operating costs, such as raw material costs, packaging costs, as well as utility costs (Marouli & Maroulis, 2005). The cost of other food production related activities should also be included in the cost accounting system, such as labour costs, supervision, waste treatment, warehousing costs, maintenance, repairs, and operating supplies (Aly & Baker, 2013:150). In a food manufacturing company, the operating cost also includes the implementation of the food safety system. The implementation of HACCP influences the processing cost of an operation, as time and skills are necessary to implement the system effectively

Zugarramurdi *et al.* (2007) developed a quality cost model applicable to food companies, which can be used to evaluate the effectiveness of the company's quality management system, with a specific focus on HACCP. Quality costs presented by (Zugarramurdi *et al*., 2007) include prevention and appraisal costs. Prevention costs involve the cost incurred by maintaining good hygiene and sanitation in the processing plant, for instance, the cost of purchasing cleaning detergents and the labour used to clean the facility. Other prevention costs include equipment and structural maintenance as well as additional supervision (Zugarramurdi *et al.*, 2007). Appraisal costs include the cost of all inspections done on raw material as well as final and work-in-progress products. It also includes the cost of product sampling and the microbiological analysis thereof (Zugarramurdi *et al.*, 2007).

2.4 Food Safety and Quality Management Systems

A Food Safety Management System (FSMS) is the result of a food company implementing appropriate and available food safety and quality guidelines and standards published by internationally recognised food safety institutions, such as Codex Alimentarius and GLOBALG.A.P. (Kirezieva *et al*., 2013). There is a global trend in the food industry with regard to the implementation of FSMS as a means to increase the quality and safety of food products and to gain additional benefits related to these systems (Kafetzopoulos & Gotzamani, 2014). The following section will discuss the general aspects of an FSMS, the details of specific FSMSs, as well as benefits relating to such systems. Literature on factors influencing the successful implementation of these systems will also be discussed.

2.4.1 Overview

An FSMS aims to address two elements in the food industry, namely food safety and food quality. Evidently, there are systems that focus purely on food safety, and then there as systems that focus on controlling food quality (Rotaru *et al*., 2005). Basic food safety systems include good manufacturing practices (GMPs), good agricultural practices, good hygiene practices (GHP) and good laboratory practices (Van Der Spiegel *et al.*, 2003). A more advanced food safety system is HACCP (Rotaru *et al*., 2005). Although HACCP was intended to be a food safety system and is still promoted as such, it is frequently applied in industry to control food quality parameters as well (Wallace & Williams, 2001). Furthermore, basic quality management systems include ISO 9001:2015 (*Quality Management Systems),* whereas a more advanced quality management system is ISO 9004:2009 (*Managing for the sustained success of an organization - A quality management approach)* (Rotaru *et al*., 2005).

However, according to Rotaru *et al*. (2005), the concept of food quality is fairly complex and can only be addressed by considering food safety. The two concepts are therefore highly integrated and, in fact, dependent on one other (Fig. 2.1). Furthermore, it is evident that systems and standards focus on different elements of a food production operation. An integrated approach towards food safety and quality management will, therefore ensure that both quality and safety, as well as managerial aspects, are included in the implemented system. Integrated systems, such as ISO 22000 and Food Safety System Certification (FSSC) 22000 (Rotaru *et al*., 2005), have been developed to address this issue. ISO 22000 was specifically developed to incorporate managerial aspects into food safety systems, such as GMP and HACCP (Kafetzopoulos & Gotzamani, 2014).

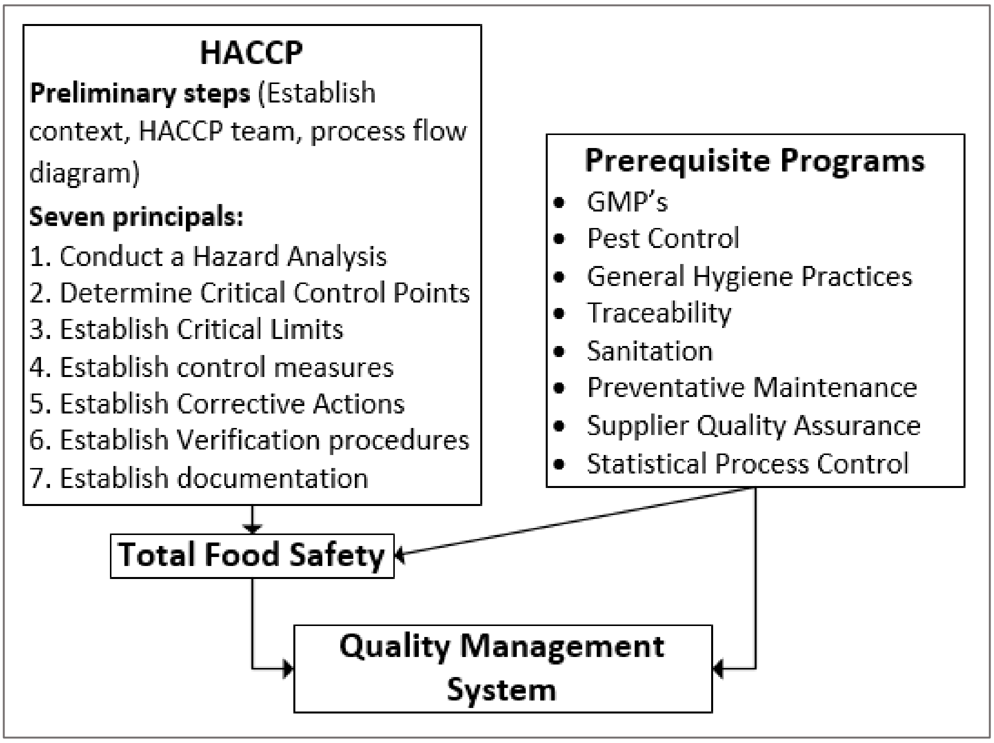

Figure 2.1 An illustration of the relationship between HACCP and PRPs in the Quality Management System of a company (adapted from Mortimore, 2001).

2.4.2 Prerequisite Programs

Various definitions of prerequisite programmes (PRPs) have been published by the food industry (Wallace & Williams, 2001), and most of these definitions acknowledge the fact that PRPs are programmes, procedures, and conditions that decrease the number of Critical Control Points (CCPs) in a factory and set the foundation for HACCP implementation (Codex Alimentarius Committee on Food Hygiene, 2003; WHO, 2006). Companies generally consider the guidelines published by the Codex Committee on Food Hygiene (2003) as the basis of PRP implementation (Wallace & Williams, 2001). Many other definitions of PRPs describe it as being the most basic programmes that can be implemented to obtain favourable environmental and operation conditions for the production of safe food (Rotaru *et al*., 2005; Wallace *et al*., 2005b).

The R962 document (2012), *Regulations Governing General Hygiene Requirements for Food Premises and the Transport of Food*, is a regulation applied by municipalities in South Africa to issue a Certificate of Acceptability for food manufacturers (Jordan, 2014). Therefore, by law, all food handlers in South Africa must be in possession of this certificate. Most of the PRPs that relate to hygiene are covered in this regulation. The next step of food manufacturers is to implement the outstanding PRPs, which can be addressed by implementing GHPs and GMPs. Rotaru *et al.* (2005) explain that there are different ways of adhering to the requirements of GMPs and that the chosen method should fit the strategic operations of the company. This is confirmed by Manning (2013), who states that GMPs should be developed in such a way that it is company-specific, product-specific and consistent in the entire production process.

2.4.3 Hazard Analysis and Critical Control Points

HACCP is internationally recognised as a system that is used to identify, assess and control possible food safety hazards in a food manufacturing company (Untermann, 1999; Hofmeyr, 2009). According to Mortimore (2001), HACCP is a straightforward system that offers a practical approach towards food safety management. The international recognition of HACCP is confirmed by the fact that the Codex Alimentarius Commission (2009) as well as the International Organization for Standardization (22000:2005), both recommend an HACCP-based approach to food safety. HACCP compliant companies, therefore, gain access to international markets and effectively have a competitive average over their opponents.

The HACCP system is governed by seven principles. The seven principles of HACCP were developed by the National Advisory Committee on Microbiological Criteria for Foods in 1988, with the aim to assist the food industry with producing safe food (Untermann, 1999). These principles were later adopted by the Codex Alimentarius (FAO/WHO, 1997). However, prior to the implementation of these principles, a few preliminary steps must be completed. These steps are part of the planning and preparation of HACCP. According to Mortimore (2001), planning and preparing are essential for successfully implementing HACCP. A major part of preparing for HACCP is to ensure that all employees involved, have a clear understanding of what HACCP implementation entails (Mortimore, 2001). This requires the commitment of management towards the system. Another important preparatory step includes the assembly of an HACCP team, as the food safety outcome of a team will be much greater than that of individual employees (Wallace *et al.*, 2012). It is the responsibility of the HACCP team leader to ensure that the employees involved share the same vision for implementing HACCP and that they understand the project goals (Mortimore, 2001). Furthermore, the HACCP team must be multidisciplinary, as knowledge of raw materials, products, production processes, and hazards are required, as well as skills related to project management, problem-solving, training and auditing (Mortimore, 2001). The HACCP team is required to conduct a baseline audit to determine which food safety programmes are not yet covered by the PRPs (Mortimore, 2001). The effectiveness of the overall FSMS will depend on the precision of the baseline audit.

Once the foundation for HACCP has been set, the seven HACCP principles can be applied (Fig. 2.1). The HACCP principles must be applied alongside documentation such as a product description and flow diagram of the primary production processes (Mortimore, 2001). The first principle of HACCP is to identify potential hazards from the point of receiving the raw materials, to the point of consumption (Codex Alimentarius Commission, 2009). This analysis is predominantly based on the primary production processes identified in the flow diagram. According to Wallace *et al*. (2014), the hazard analysis forms the centre of the HACCP system, as control measures can only be prescribed once the hazard is identified and understood. The hazard analysis focusses on evaluating risk according to the effect its occurrence would have on the health of the consumer.

The second principle involves the identification of Critical Control Points (CCPs) from the identified hazards. A CCP is described as a step in the production process at which control is essential to prevent a food safety hazard from occurring or reduce it to a suitable level (Doménech *et al*., 2008). A distinction between control points (CP) and CCPs can be made by taking each identified hazard through the CCP decision tree (Manning, 2013). According to Mortimore (2001), the selection of appropriate CCPs is crucial, as the choice of managing some prerequisite programmes as CCPs will undermine the effectiveness of the system. CCPs require significantly more control and effort, and it would be impossible to control all the steps in the production line to this degree.

Specifying and validating measurable critical limits for each CCP is the third principle of HACCP (Codex Alimentarius Commission, 2009). A critical limit is described as a minimum or maximum value to which process parameters at a CCP should be controlled, or that would otherwise result in unsafe processing conditions (Doménech *et al*., 2008). It should be kept in mind that process control parameters are not equivalent to critical limits, as process control parameters are not generally established for food safety reasons (Mortimore, 2001; Doménech *et al*., 2008).

Principle 4 of the HACCP system involves the formation of monitoring procedures for each CCP (Codex Alimentarius Commission, 2009). A monitoring procedure is the scheduled observation of a CCP relative to its critical limits (Codex Alimentarius Commission, 2009). The monitoring procedure must be able to detect loss of control when process deviations at CCPs occur (Doménech *et al*., 2008). Generally, detection of deviations occurr through means of computerised detectors and alarms (Doménech *et al*., 2008), after which corrective actions are necessary (principle 5). According to Mortimore (2001), the established corrective actions must be able to regain control of the process, and should effectively deal with the non-conforming product.

The final two principles of HACCP is important for ensuring the long-term success of the HACCP system. Verification procedures (principle 6) can be described as evaluation methods used to determine the compliance of the operation with the HACCP plan and essentially, to determine if the HACCP system is working (Taylor, 2001; Codex Alimentarius Commission, 2009). Verification activities may include physical testing and analysis of product samples, auditing the HACCP plan, reviewing of corrective actions, CCP monitoring records as well as customer complaints (Mortimore, 2001; Manning, 2013). These activities must be conducted on a regular basis in order to integrate organisational change into the system. The 7th HACCP principle involves the development of an efficient record-keeping system (Codex Alimentarius Commission, 2009). The record-keeping system includes documentation such as the HACCP plan, CCP monitoring records, training records, records of reviewing, verification activities and amendments to the system (Mortimore, 2001). Perminova *et al*. (2008) state that documentation should not be regarded as an administrative requirement, but rather as a tool for information collection, system integration, evaluation, and proactive decision-making.

2.4.4 Factors Influencing the Effectiveness of HACCP

The implementation of quality and safety management systems is generally linked to benefits such as increased productivity and lower production costs, as well as improved consumer satisfaction and consumer trust (Dora *et al.*, 2013). However, it is commonly asserted in literature that these benefits of HACCP are only realised if the system is properly implemented (Kafetzopoulos & Gotzamani, 2014; Fotopoulos *et al.*, 2009; Mortimore, 2001). In literature, critical areas that influence the effectiveness of a food safety system are presented (Fotopoulos *et al*., 2011). According to Wallace *et al*. (2014), these critical factors or areas should be carefully examined by companies in order to successfully manage them and to achieve the effective implementation of the HACCP system.

Research conducted by Fotopoulos *et al.* (2011) indicated that the main factor hindering the effective implementation of HACCP is the limited knowledge and skills of employees. According to Panisello and Quantick (2001), education and training are one of the four pillars of a successful HACCP system. It is further commonly asserted in literature that adequate employee training is crucial to the success of HACCP (Mortimore, 2001; Manning & Baines, 2004; Ball *et al.*, 2009; Fotopoulos *et al.*, 2009). Evidently, employees involved in the implementation of HACCP should receive effective and high-quality training before the implementation of HACCP. The training should also be conducted by professionals with practical experience in the field. Once the HACCP plan has been established, employees must be trained to manage the identified CCPs (Jevšnik *et al.*, 2008). According to Jevšnik *et al*. (2008), companies implement employee training programmes without taking the general requirements of such programmes into consideration and without realising the importance of the matter. In addition, they are seldom capable of assessing the food safety knowledge of their employees. Managers tend to place emphasis on obtaining food safety certification, rather than focussing on their staff achieving competency in food safety practices (Jevšnik *et al.*, 2008). Many companies in the food industry consider a single training session sufficient for maintaining an effective HACCP system, but the exact opposite is suggested by food safety experts (Wallace *et al*., 2005a). The necessity for continuous training and development, especially in small organisations, is proclaimed by Taylor (2001), who states that employees should be guided through the process and not be abandoned after the initial food safety course.

Another critical factor identified by Fotopoulos *et al.* (2011) is the lack of employee commitment, attitude, and motivation concerning food safety systems. According to Panisello and Quantick (2001), managerial commitment is one of the four pillars of the successful implementation of an HACCP plan. The commitment of managers should be the driving force behind implementing all the necessary PRPs and applying the seven principles of HACCP (Panisello & Quantick, 2001). It is well asserted in literature (Mortimore, 2001; Fotopoulos *et al*., 2009; Manning, 2013) that the HACCP system should be supported by a thorough record-keeping trail and that the lack of supportive documentation may hinder the performance of an FSMS. A thorough record-keeping system will only be implemented by committed managers. The lack of managerial and workforce commitment will thus result in a lack of resources to form a solid foundation for the HACCP system (Panisello & Quantick, 2001). However, Taylor (2001) states that in small businesses, the commitment and motivation of managers with regard to implementing HACCP is less irrelevant if time and financial resources are limited. The implementation of HACCP can result in a major financial burden for small companies; therefore, the availability of resources is also a critical factor.

Furthermore, the attitude of employees towards implementing food safety systems can be influenced by the food safety culture within the company, the degree of job satisfaction and the relationship between employees and managers (Jevšnik *et al.*, 2008). Fotopoulos *et al.* (2009) further state that employees generally have a negative attitude towards implementing food safety when they lack interest in their work. Thus, it is important for an effective food safety system to be characterised by an appropriate combination of employee attitudes, values and opinions within the company. (Wallace *et al.*, 2014). Figure 2.2 presents a model created by Wallace *et al*. (2014) that can be applied in order to obtain an effective HACCP system.

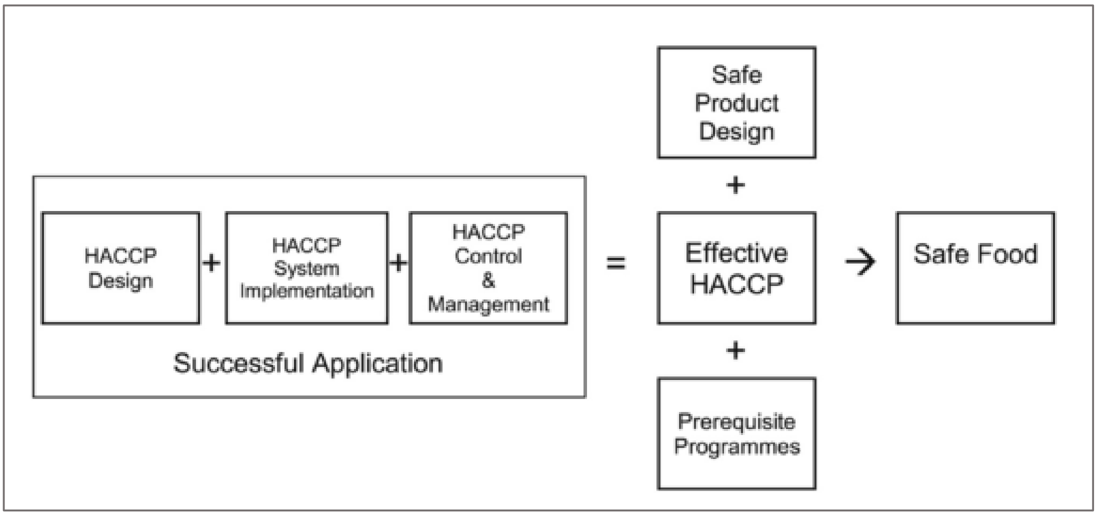

Figure 2.2 A model for achieving an effective HACCP system (Wallace *et al.*, 2014).

2.4.5 FSSC 22000

The FSSC 22000 certification scheme was published in 2009 by the Foundation of Food Safety Certification and was approved by the Global Food Safety Initiative (GFSI) in 2010 (Soares *et al.*, 2016:129). FSSC 22000 is a complete FSMS that is based on the ISO 22000:2005 (*Food Safety Management Systems*), ISO 17025:2005 (*General requirements for the competence of testing and calibration laboratories*) and Publicly Available Specification (PAS) 220:2008 (*Prerequisite programmes on food safety for manufacturing*) standards (Soares *et al*., 2016:130). However, it has additional requirements concerning managerial aspects. The PAS 220:2008 standard was originally established to assist food manufacturing companies with the management of PRPs, but has since been withdrawn, as most of its content is now available in the ISO 22002-1:2009 (*Prerequisite Programmes on Food Safety*) standard (Manning, 2013). The ISO 22000:2005 standard is not approved by the

GFSI because the scheme poorly defines the requirements for implementing PRPs (Newslow, 2014:8). Nevertheless, Newslow (2014:8) states that ISO 22000:2005 compliant companies can incorporate ISO 22002-1:2009 into their systems in order to become a GFSI approved the scheme.

The FSSC 22000 scheme was established for the certification of food safety systems and was specifically developed for companies in the food industry (Newslow, 2014:9). This DFSI approved scheme has many benefits, but the degree to which value is added will depend on the structure and goals of the company. It provides a flexible framework that allows management to choose the best approach for their specific company. A significant advantage of the FSSC 22000 scheme is that the format is based on that of ISO 9001 *(Quality Management System Requirements).* The ISO 9000 series aims to provide companies with a framework for implementing a quality management system and offers continuous improvement strategies (Kafetzopoulos & Gotzamani, 2014). The FSSC scheme, therefore, encourages the implementation of ISO 9001 by simplifying the integration process of the two systems. According to Newslow (2014:9), the FSSC 22000 scheme is a management system certification scheme, and not a product or process certification scheme. The scheme, therefore, focusses on management commitment, the effectiveness of the system and continuous improvement in the company (Newslow, 2014:10). It can be said that FSSC 22000 certification is a definite food safety goal of any food manufacturing company that aims to attract the international market.

2.5 Risk Management

The goal of this research was to develop a risk management framework for the company in question. The following section aims to meet the first objective of this study, which was to investigate different risk management frameworks as well as risk management techniques in the food industry.

2.5.1 Risk and Risk Management Principals

According to the ISO 31000:2009 (*Risk Management—Principles and Guidelines)* standard, risk can be defined as the likelihood of an event occurring, in which case the occurrence may hinder a company from achieving its organisational goals. It is therefore in the best interest of any company to seek a method to manage and minimise these risks.

Many different definitions of risk management exist, but the definition published by ISO 31000:2009, in which risk management is the complete process, is applied in this study. Risk management is defined as a process by which the identified risk is analysed based on the probability of the risk occurring, and the nature and impact of the potential effect (ISO, 2009). Furthermore, Berg (2010) states that risk management can be used as a tool to facilitate decision-making if an occurrence at an activity level or in a larger area, threatens the achievement of company goals. These decisions must especially be made if the estimated risk level, obtained through analysis, is higher than the acceptable risk level of a certain process or product (Schlundt, 1999).

Much research has been done (Raz & Michael, 2001; Ward & Chapman, 2003; Ahmed et al., 2007; Airmic & Alarm, 2010; Berg, 2010; Purdy, 2010) on risk management and today risk management is applied in various forms and in any industry. The ISO 31000:2009 standard was published in an attempt to re-establish the basic principles of risk management and to obtain risk management consistency in all industries (Purdy, 2010). The standard was developed by consulting experts that are involved in different aspects of the subject and from different countries in order to create a standard that is applicable to any form of risk (Purdy, 2010). Risk management is no longer seen as an individual or separate system, the industry is moving towards a more integrated approach due to all the different forms of risk that have emerged (Berg, 2010). A successful and integrated approach requires the risk management system to align with other activities and systems within a company. Nevertheless, it is suggested in the ISO 31000:2009 standard that risk management should be the centre of any company's management system and that the application of risk management shoud be considered in all decision-making processes (Purdy, 2010).

2.5.2 The Risk Management Framework

The process termed "risk assessment" is regarded as the central procedure of risk management (ISO, 2009), but before risk assessment can commence, it is important to establish a context for the risk management system in terms of company goals and other influential factors (Berg, 2010; Purdy, 2010). Berg (2010) states that it is important to understand the environment in which the company operates as this will influence the level and characteristics of risk in the company. The risk management system should be structured according to the level of risk in a company in order to be successful (Airmic & Alarm, 2010). Factors influencing the level of risk include the size of the company, the complexity of its systems and the type of product it produces (Airmic & Alarm, 2010). Berg (2010) suggests that a context for the risk management system can be established by reviewing regulatory requirements of the specific industry, as well as related codes or standards.

Once the context has been established, risk assessment can follow. Risk assessment comprises of three different processes (ISO, 2009). The first is described as the process of identifying potential risks. Any event that can hinder the achievement of company goals and the source thereof should be identified at this point (Ahmed *et al.*, 2007). Different methods can be applied to identify risks and will depend on the nature of risk, and the available resources as well as regulatory requirements applicable to the type of industry (Berg, 2010). Berg (2010) suggests that people with appropriate knowledge regarding the operations of the company can be valuable during this process and should be consulted.

The second process in risk assessment is risk analysis. The aim of risk analysis is to determine the level of risk for a specific situation, by determining risk consequence and risk probability (Berg, 2010; Purdy, 2010). Berg (2010) and Purdy (2010) state that either quantitative or qualitative methods can be used to analyse the identified risk, but that the method must correspond to the type of risk being analysed, the type of data available, and the purpose of analysing the risk. Usually, the more critical risks will be analysed via quantitative techniques, whereas qualitative and semi-quantitative techniques are generally used to screen risks (Berg, 2010). Berg (2010) states that the information or data needed to conduct risk analysis must be gained from employees at all levels of the company as risk covers a wide spectrum of an organisation. Risk analysis also involves the calculation of the expected loss in monetary value associated with a specific risk, if such data is available (Kaliprasad, 2006).

Once the risk level has been established, an evaluation of the risk is conducted. During the evaluation process, risks are prioritised according to expected losses so that an appropriate risk treatment can be suggested (Berg, 2010; Purdy, 2010; Ahmed *et al.*, 2007). Control measures or risk treatments are not considered if control of the risk is not cost effective, if there is no appropriate control measure available, or if the risk potentially poses more opportunity than risk (Berg, 2010). If the risk does not qualify for a control measure, it is deemed as acceptable, but should still be monitored (Berg, 2010). All other risks are considered unacceptable and should be actively managed. Kaliprasad (2006) states that it is important to remember that risks are linked to certain points in time, meaning that the level of risk may change with time. Effectively, the risk management system should be validated on a regular basis.

Once a risk is deemed unacceptable, a risk treatment strategy should be developed (ISO, 2009). Purdy (2010) states that the treatment of risk involves altering the probability of its occurrence as well as the impact of its occurrence. In effect, the risk will be controlled to the advantage of the company. Standard risk treatments exist such as avoiding the risk, reducing the risk, transferring the risk or accepting the risk (Berg, 2010). Information regarding the possible reduction of the probability or impact of the risk will assist with identifying a suitable treatment. According to Kaliprasad (2006), the first step to developing an action plan is to consider if the risk can be avoided or transferred.

Literature suggests that the final step in the risk management system is to constantly review and monitor the proposed control measures against the organisational goals (Berg, 2010; Purdy, 2010; ISO, 2009; Kaliprasad, 2006). As previously mentioned, risks are subject to change due to internal and external factors and so are the goals of the organisation. The risk management system should be adapted accordingly through monitor and reviewing processes. Furthermore, Berg (2010) states that it is especially important to consider legislative change when conducting the review. Upon the reviewing process, frequent communication among stakeholders should also be conducted with regard to the performance of the risk management system and achievement of company goals (ISO, 2009). Figure 2.3 illustrates the risk management framework that has been discussed in the sections above.

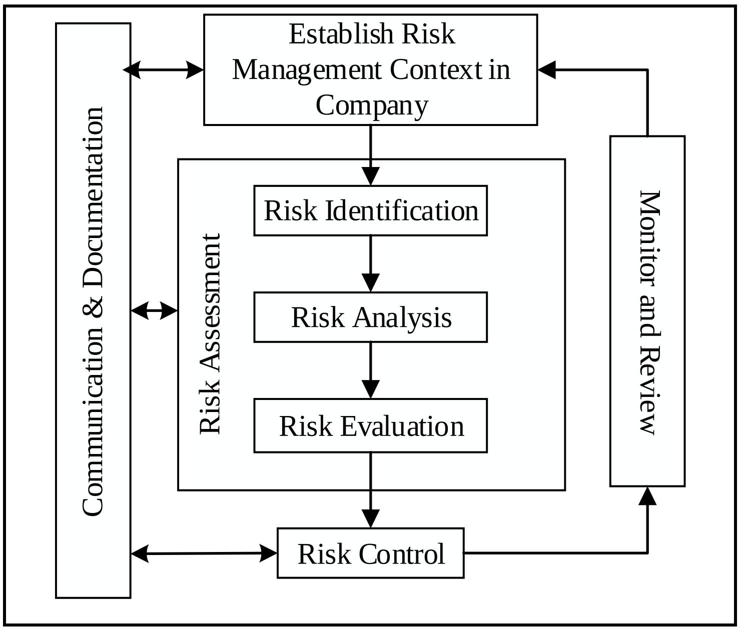

Figure 2.3 The risk management framework as proposed by ISO 31000:2009.

The ISO 31000:2009 risk management standard provides a generic framework (Fig. 2.3) for risk management that can be adapted and revised according to an organisation's internal procedures, business structure, identified risks and general policies (Purdy, 2010). Although a lot of detail is given about the implementation of risk management systems, the standard still lacks practical guidance as to the implementation of risk management in a company. Companies continue to struggle with the implementation of an effective risk management strategy into their management systems (Purdy, 2010).

The effective implementation of a risk management system requires the establishment a risk management culture within the company. Employees on the floor should receive proper education and training with regard to identifying and dealing with risks in an effective way (Kaliprasad, 2006). Additionally, managers and supervisors should be highly educated on the subject so that they may assist and motivate employees on the floor in the initial stages of implementing the project (Kaliprasad, 2006). Furthermore, it is important that employees honour the vision, mission, and objectives of the company as part of the risk management culture (Berg, 2010). The risk management culture will also require employees to act proactively rather than reactively when controlling risks (Kaliprasad, 2006).

It is clear that employees play a major role in the implementation of new systems in a company. The implementation of such a complex and unfamiliar system may be intimidating to employees and the change to be experienced in the company should be managed properly. Various change management strategies will be discussed in a later section.

2.5.3 Risk Management Systems in the Food Industry

In the previous section, the implementation of a generic risk management system was discussed. In the following section, more focus will be placed on risk management and similar systems being applied in the food industry. Food manufacturing companies predominantly focus on risks associated with food safety, as the food they produce is likely to have an effect on the health of the consumers.

In a food and nutrition report (1997), published through a joint consultation of the Food and Agricultural Organisation of the United Nations (FAO) and the World Health Organisation (WHO), a risk in terms of food safety is defined as the probability of a contaminated food product causing an adverse health effect, by considering the severity of the effect. Additionally, the term "hazard" is often used when food safety is discussed. The Codex Committee on Food Hygiene published a food hygiene standard in which a hazard is defined as an activity or occurrence that can induce either a biological, chemical or a physical contamination that may be harmful to the health of the consumer (Codex Alimentarius Committee on Food Hygiene, 2003). The Codex Alimentarius is a set of codes, guidelines and standards jointly published by the FAO and WHO with the aim to synchronise international food trade standards and in effect, to protect the health of consumers on a global level (FAO/WHO, 1997).

The FAO, together with the WHO, further state that it is important to understand the association between risk analysis and hazard analysis when developing food safety controls (FAO/WHO, 1997). Hazard analysis is a process that is applied in the Hazard Analysis and Critical Control Point (HACCP) system. The hazard analysis process in HACCP entails the identification of biological, chemical and physical hazards in the production process of a specific food item in a production facility. Upon the identification of the hazards, each hazard is assessed in order to determine whether the elimination or reduction to acceptable levels is essential to the production of a safe food. Each food safety hazard is then evaluated according to the possible severity of adverse health effects and the likelihood of its occurrence. Finally, the obtained risk rating will be used, together with a decision tree, to determine if a Critical Control Point (CCP) must be established (Untermann, 1999). However, HACCP fails to provide quantification methods and thus does not quantify the impact of control methods on the probability of the hazard (Pérez, 2012:127).

The main difference between risk analysis and hazard analysis is in the output of these two systems (Oyarzabal, 2015). Risk analysis delivers complex results regarding the probability and severity of a specific hazard and suggests a multistep approach towards managing the hazard (Oyarzabal, 2015). However, risk analysis has become a popular topic in the food industry. The FAO together with the WHO has published various guidelines concerning food safety and risk analysis (FAO/WHO, 1995; FAO/WHO, 2006). Additionally, reports have also been published regarding the implementation of risk management in food safety systems (FAO/WHO, 1997).

According to the food safety risk analysis guide published by the FAO and WHO, risk analysis should be implemented in food manufacturing companies in order to control food safety hazards effectively (2006). The report states that risk analysis comprises of three elements: risk assessment, risk management, and risk communication (Fig. 2.4). This is different to the ISO 31000:2009 framework discussed in the previous section where risk management is seen as the complete system. The definitions of risk and risk management differ depending on the type of industry and the need for such a system. It is clear that the food industry has adopted a risk management system in which the terms differ slightly from that of ISO 31000.

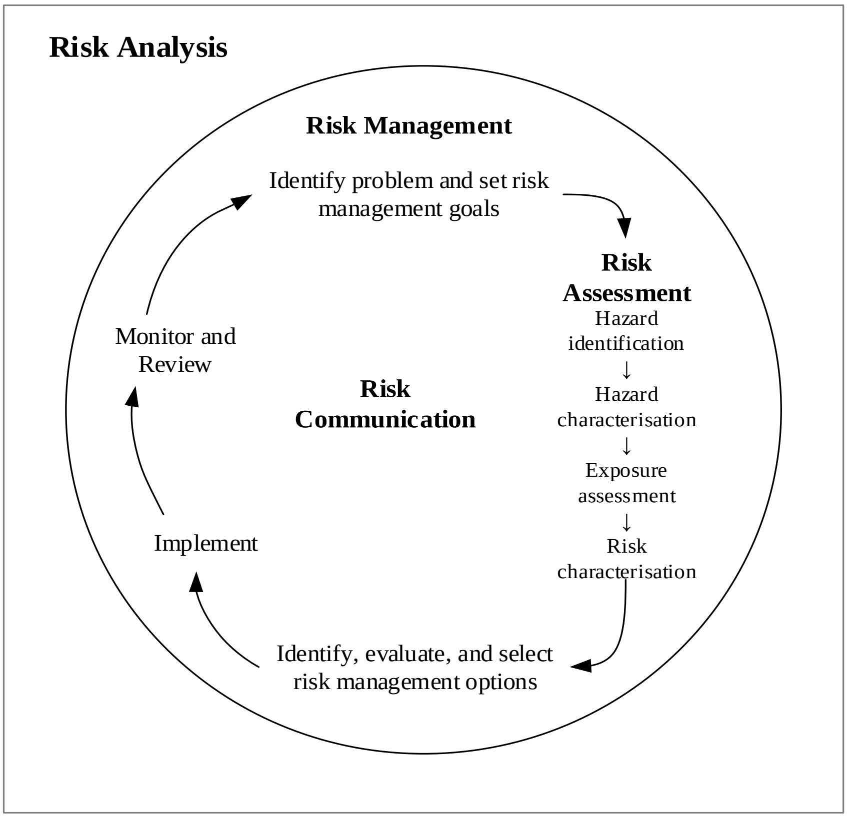

Figure 2.4 Risk analysis framework according to FAO and WHO (2006).

Nevertheless, the risk assessment element in the FAO and WHO joint report requires scientific effort and comprise of these steps: hazard identification, hazard characterisation, exposure assessment and risk characterisation (1995). Furthermore, the paper describes risk management as being the process in which the significance of the identified risk is established and the probability of the risk is reduced through cost-effective control measures. The final element of risk analysis, known as risk communication, is described as the process of communicating results of risk assessment and risk management to all stakeholders in the value chain (FAO/WHO, 1995). It can be seen that the steps of risk analysis in food safety is similar to the steps of risk management provided by the ISO 31000:2009 standard, but is published in the sole context of food safety as influenced by foodborne agents (FAO/WHO, 1995).

The discussed risk analysis and food safety reports provide detailed frameworks for risk analysis where the system is focussed on identifying and controlling risks that are associated with food contamination or food safety. As previously stated, the identification of food safety risks are essential to a food manufacturing company, but there are other types of risk from a business point of view that may have an effect on the sustainability of a company. These risks should, therefore, be considered in the risk management framework of a food company.

2.6 Implementation of HACCP and Change Management

The implementation and integration of various systems will require a certain degree of change in a food company. This is especially true in a newly established company such as BKT, which is only at the early stages of implementing HACCP. This type of change will not only involve the system itself, but also the attitude and mindset of the workforce. The change must be implemented in an integrated manner in order to achieve the best possible outcome. This process is known as Change Management.

HACCP covers different aspects of food safety than that of GMPs; therefore, changes will be made in a factory in order to make it HACCP-compliant. The prerequisite programmes (PRPs) that are already in place should be noted and thereafter a gap analysis should be conducted in order to determine which programmes should still be implemented according to HACCP (Mortimore, 2001). This is an important part of HACCP planning as any gap in the quality management system may lead to potential hazards.

The implementation of HACCP, therefore, induces significant change in the processing line, which could have major effects on the employees working on the line. The implementation of HACCP is generally accompanied by training courses that educate workers on the programme before it is put in place. There is a possibility of staff resistance if the change is significant. Basic education on the subject may not be sufficient to address the resistance effectively. The change induced by altering food safety programmes should, therefore, be well managed in order to ensure successful implementation of the HACCP system.

Furthermore, the implementation of HACCP cannot be successful without proper monitoring and validating procedures (Mortimore, 2001). Factors such as the product, production process or employees, may change after the initial implementation of HACCP. This will require a validation of the HACCP programme to ensure that the change in the facility is incorporated into the safety or quality management system.

According to Panisello and Quantick (2001), there exists barriers that prevent the successful implementation of changes related to HACCP. These barriers can be present before, during or after the implementation of HACCP and include actions from management and personnel or can include factors related to infrastructure (Panisello & Quantick, 2001).

Hayes (2014:5) argues that the management of change should be handled out of a process perspective, as the focus will then be on how the transformation should occur. He suggests that the successful implementation of a system depends on how effectively the new aspects of the system is integrated with the organisational environment. Successful implementation is more likely when there is a strategic fit between the change being implemented and the overall strategy of the firm.

Hayes (2014:5) states that the type of change to be induced in a company must first be established. Four different theories or types of change are identified and discussed: teleological, dialectical, life cycle and evolutionary theories (Hayes, 2014:5). Each change theory is characterised by a different purpose. The teleological theory is applicable when companies specifically induce a change in order to accomplish certain organisational goals (Hayes, 2014:5). The dialectical theory suggests that change is brought about due to conflicting opinions in a company (Hayes, 2014:5). The life cycle theory suggests that the change experienced is part of an ongoing process that has a specified sequence of events (Hayes, 2014:5). Lastly, the evolutionary theory suggests that change is a continuous cycle where the best strategic fit is selected at each stage (Hayes, 2014:5). It can be said that the change experienced in a company where HACCP is being implemented and validated, is part of the teleological theory, as it is a calculated change and the company aims to move towards a defined outcome.

Furthermore, Hayes (2014:26) identified seven crucial steps of managing change. In the first step, the need for change in the company must be identified resulting in the process of change being initiated. According to Panisello and Quantick (2001), food manufacturing companies feel the pressure to implement the HACCP system from consumers, regulatory bodies or governments, media as well as international traders. Companies in the seafood industry especially feel the need to implement HACCP due to fish being associated with high risk. Research must be conducted in this step of the change management process to establish if the change is necessary and if the time for implementation is right (Hayes, 2014:27). Once it is established that the change is necessary, the process is initiated by informing relevant parties and by motivating them to accept the change (Hayes, 2014:27). Hayes (2014:28) states that it is important to appoint a motivated and committed employee to initiate and direct the change. Literature (Mortimore, 2001; Panisello & Quantick, 2001) suggests that the commitment of senior management fuels the formation of effective PRPs and the implementation of HACCP principles.

The second step in the change management process, according to Hayes (2014:26), is to evaluate specifically where and what change is needed in the company. This step is approached either by evaluating the present state or by establishing goals for the future state (Hayes, 2014:28). In terms of implementing HACCP, the present state can be evaluated through a gap analysis or a baseline audit (Mortimore, 2001). The gap analysis will involve the identification of deficiencies in the current food safety system (Mortimore, 2001). This will assist with defining the degree to which the current process must change. In addition, during a future state evaluation, the effect of the process on the organisation is forecasted (Hayes, 2014:29).

According to Hayes (2014:30), different types of change require different planning strategies. The development of a change strategy forms the basis of the third step in the change management process (Hayes, 2014:26). The aim of this step is to determine how the goals of the change process will be achieved (Hayes, 2014:30). It is important to allocate resources, such as time, money and employees to certain tasks, and to prepare for unexpected events, to ensure that calculated and informed decisions are made throughout the change process (Hayes, 2014:30).

Workforce resistance must also be accounted for during the planning phase. Hayes (2014:31) states that the implementation of change may not go as planned due to the workforce resisting the change. According to Kotter and Schlesinger (2008), there are four types of resistance that can be experienced from the workforce. Firstly, employees may feel that they are going to lose something that is of value to them, for instance, their positions in the company (Kotter & Schlesinger, 2008). Secondly, employees may misunderstand the consequences of the change and the way it will affect them. This type of resistance is usually a result of mistrust between management and employees (Kotter & Schlesinger, 2008). The third type of resistance is experienced when employees assess the outcome of the change differently than the managers (Kotter & Schlesinger, 2008). This resistance could surface due to lack of information-sharing between the two parties. Lastly, Kotter and Schlesinger (2008) states that workforce resistance can possibly occur due to the inherent nature of people simply not tolerating change. This often occurs when employees feel insecure about their abilities in their work environment.

The change strategy will partially be based on the type of resistance expected from the workforce. According to Kotter and Schlesinger (2008), five effective change strategies deal with employee resistance. In addition, time on hand, as well as the end vision of the project play an important role when deciding on a strategy (Kotter & Schlesinger, 2008; Hayes 2014:31). The most common change strategy is education before implementation (Kotter & Schlesinger, 2008). Employees are educated on key aspects related to the change process in order to avoid misconceptions. Another change strategy involves the training of employees in an attempt to increase their self-confidence (Kotter & Schlesinger, 2008). In addition, Panisello and Quantick (2001) suggest that education and training is one of the four pillars of successful HACCP implementation. This is confirmed by Mortimore (2001) who states that it is beneficial to the company if all employees have a basic understanding of HACCP and how it affects their working environment. Furthermore, CCP monitors on the production line must undergo more in-depth training with regard to the understanding, handling, monitoring and control of CCPs in the production environment (Mortimore, 2001).

The third change strategy suggested by Kotter and Schlesinger (2008) involves the participation of employees in the change process. This strategy facilitates communication between management and employees and establishes a measure of trust between the two parties. Mortimore (2001) states that positive involvement of employees will be achieved if employees are made aware of their specific role in the food safety system and if teamwork is encouraged in the work environment.

Another change strategy by Kotter and Schlesinger (2008), involves a negotiation between management and employees where an agreement is settled that satisfies both parties. For instance, incentives can be offered if the workers agree to embrace the change. In a study conducted by Robbins and McSwane (1994), it was determined that employees did not implement new sanitation procedures because they did not receive remuneration for the extra work, such as studying the procedure manual. This strategy may be effective, but the availability of resources must first be evaluated before considering this approach.

Other change strategies include manipulation and co-optation of employees by managers (Kotter & Schlesinger, 2008). In this strategy, managers choose to share only certain information with the employees in order to get their approval. Employees may react negatively towards this method, as they may feel tricked into complying (Kotter & Schlesinger, 2008). Huss (1992) states that the proper implementation of HACCP requires trust between supervisors and employees. Following this change strategy might jeopardise that trust which may lead to the failure of the HACCP system. The final change strategy discussed by Kotter and Schlesinger (2008) is when managers threaten employees to accept the change or otherwise give up their jobs (Kotter & Schlesinger, 2008). This method poses a great deal of risk, as employees will most likely resent the change that has been forced upon them. However, this method will be effective when time is limited and when management has no further options (Kotter & Schlesinger, 2008).

The fourth step in the change management process, according to Hayes (2014:30), is the implementation of the change strategy and reviewing. Hayes (2014:30) states that it is important to monitor the change process after the strategy has been implemented to determine its effectiveness and validity. In terms of implementing HACCP, monitoring and validation procedures are part of the seven principles of HACCP and are crucial for its long-term success (Mortimore, 2001). The HACCP plan takes into consideration that processes, products, and employees may change and therefore incorporates validation procedures. Some of these procedures include ongoing audits, data analysis and record keeping (Mortimore, 2001).

The fifth step in the change management process is to sustain the change (Hayes, 2014:26). According to Hayes (2014:34), several factors can undermine the sustainability of change. For instance, the change strategy that was implemented has a major influence on the sustainability of the change (Hayes, 2014:34). Care must be taken to choose a strategy that will facilitate long-term commitment from personnel (Hayes, 2014:34). Forced change would most likely be unsustainable. Hayes (2014:34) states that managers can attempt to sustain the change by reminding employees of the vision and goal of the change. In addition, change can also be sustained by providing newly appointed managers with appropriate training (Hayes, 2014:35). The final two steps of the change management process include managing employee issues and continuous learning (Hayes, 2014:26). These steps focus on improving the management skills of the people that lead the change. It is important that managers learn from their mistakes and previous experiences so that they improve their performance for the future.

It is seen that the implementation of HACCP, and any other FSMS, is a large project that will require a major change in a company. The change must be managed effectively so that the real benefits of HACCP can be experienced.

2.7 Summary

This chapter was used as a research method to accomplish the first research objective of this study, which was to investigate various risk management frameworks and the application of risk management in the food industry. It was established that the generic risk management framework proposed by standard-setting bodies should be adapted so that it aligns with the organisation’s corporate strategies, internal management systems, and daily operations. Furthermore, this chapter also sets a foundation for the Methodology chapter in the sense that the chosen research methods are supported by relevant literature.

3. RESEARCH DESIGN AND METHODOLOGY

The methodology chosen to conduct the research for this study are discussed. The research methods provided the tools with which the risk management framework was formulated and allowed for the identification of specific risks within the catfish processing plant. The methodology, therefore, assisted with achieving the first and second objectives of this study. The first objective of the study was to develop a risk management framework that aligns with the quality and safety management system of the catfish processing pilot plant by investigating different risk management frameworks and risk management techniques applied in the food industry. The second research objective was to suggest strategies to control the identified risks. The Methodology chapter discusses the tools with which the second research objective was achieved, however, the proposed control strategies will be discussed in the fourth chapter. The aim of this chapter is thus to form a foundation for the *Results and Discussion* chapter.

3.1 Ethical Considerations

The subject of this research is the production line of a food manufacturing company. Therefore, it involves the workforce of the production line, as well as the food safety system that is implemented in the facility. In order to keep the research from harming the employees of the company and the company itself, ethical clearance was obtained from Stellenbosch University's Research Ethics Committee prior to the investigations.

Classified documentation with regard to the food safety system of Blue Karoo Trust (BKT) were viewed and analysed during this study. In addition, information and data concerning the production processes of BKT were also investigated. It was, therefore, necessary to obtain written permission before continuing with the research. Written permission was obtained from both Cape Peninsula University of Technology (CPUT) and BKT, as access was needed to the pilot plant at CPUT. In the written consent form obtained from BKT, it was stated that the company acknowledges the fact that the catfish processing research will potentially be published in academic literature. Furthermore, the sensitive information concerning BKT was stored on a private computer that was password protected.

Ethical considerations were also made for the employees who participated in the study. The direct observation technique involved all the employees on the production line. Video recordings of the production process were also stored on a private computer that was password protected. Information obtained from the direct observation technique was not linked to any specific employee, as the identities of the employees were not significant to the study.

Two groups of employees were interviewed. The first group consisted of the production line employees and the second group involved the managers and supervisors of the production line. The only prerequisite was that all participants be full-time employees of BKT. Therefore, employees working at the CPUT-based pilot plant were interviewed, but not the employees at Le Cap Foods. The demographic information of the participants was insignificant to this study; thus, minimal personal information was requested from the participants. All of the interviewees, from both groups, were asked to sign a consent form before the interviews commenced. The consent form explained the purpose of the investigation and assured the employee that their participation will not affect their employment status in any way. The participants were also informed that they could refuse to answer a question or stop the interview at any moment. Furthermore, the identities of the interviewees were kept confidential to ensure that the information obtained from the study could not be traced back to them.

3.2 Research Design

The research design was specifically chosen in order to lead the researcher to applicable research methods. The current study employed a mixed method research design, which means that research methods of both qualitative and quantitative nature were applied. Qualitative and quantitative methods were chosen to complement one another so that different aspects of the study could be merged. The current research design was chosen due to the inherent nature of the subject of this study, namely risk. Risk can be approach by either qualitative or quantitative techniques, as proposed by Purdy (2010).

3.3 Research Methodology

The following research techniques were used to collect quantitative data as well as qualitative information from the catfish processing pilot plant based at CPUT and Le Cap Foods and assisted with the development of a company-specific risk management framework.

3.3.1 Literature Review

A literature review was done on risk management systems established by different industries. The various risk management frameworks were compared and critical aspects or steps of such a system were established. These critical steps (Fig. 2.2) were used as a guideline for the development of the company-specific risk management system. The first objective of this study was achieved by conducting this literature review.

Furthermore, a literature review was conducted on food safety and quality management systems in the food industry, with a specific focus on prerequisite programs (PRPs) and Hazard Analysis and Critical Control Points (HACCP). The review established a context for the risk management system. It also provided useful insight into the type of risks to be managed in a food-manufacturing environment in order for a company to adhere to legislation. Furthermore, the application of change management during the implementation of HACCP was investigated in literature. The investigation provided insight into how the proposed risk management framework can integrate with the quality control and Food Safety Management System (FSMS) established in the catfish processing pilot plant.

Finally, literature related to the design of food processes was studied. Focus was placed on the quality, time and cost implications of food production systems, as these three elements were identified by Perminova *et al*. (2008) as the three pillars of any given project. The literature study provided valuable information concerning risk-controlling techniques and assisted with achieving the second research objective of the study.

3.3.2 HACCP Document Review

Secondary data analysis was conducted in the form of analysing organisational documents with the aim to obtain information regarding the background of the company. The FSMS of the catfish processing operation was a major focus of this study; therefore, private company documents concerning PRPs and HACCP of Le Cap Foods and the CPUT based pilot plant were viewed. The content of these documents was used to create a detailed flow diagram of the catfish production process at the pilot plant. This will be discussed in more detail in the *Flow Diagram Development* section. The documents were also analysed to determine the food safety goals of the company, thereby establishing a context for the risk management system.

Furthermore, the record-keeping ability of the managers was established by viewing the historical processing documentation. Focus was placed on the Process Control and Product Release form, the Corrective Action Reports, and the Cold Store Temperature Checklist. The degree to which these forms were completed, provided an indication of the level of control managers have over the processing procedures and the degree to which HACCP documentation is kept in the company. The results obtained from viewing these documents were validated, to a certain degree, by interviewing the supervisors and managers of the production line. Arguments were made concerning possible risks in the company and control measures were proposed. The inspection of these documents supported the identification of risks in the catfish processing plant, thus assisting with the achievement of the second research objective of the study.

3.3.3 Flow Diagram Development

The information obtained from the PRP documents and the HACCP plan was used to design a flow diagram of the catfish processing line from receiving the raw material, to heat processing the fish. Generally, the purpose for which a diagram is created will determine the type of diagram to be used. A process flow diagram (PFD) of the production line rather than a process block diagram (PBD) was created, as according to Maroulis and Saravacos (2003:25), PFDs present more processing details than PBDs. As presented in Figure 2.1, developing a flow diagram is one of the preliminary steps to developing an HACCP plan. The type of flow diagram created prior to developing the HACCP plan, was regarded as a PBD, as no additional information regarding the process was given. This study required a more detailed flow diagram of the production process.

The information provided by the HACCP plan of the pilot plant at CPUT and Le Cap Foods assisted with the development of a PFD representing the ideal production process in the catfish processing plant. The production line of the primary product, i.e. fish mince cooked in a retort pouch, was studied, as HACCP plans were not developed for the by-products. Details of the prescribed procedures at each step, as stated in the PRP documentation of the pilot plant, were added to the PFD. In addition, different layers of the PFD were created, each presenting either product flow (Appendix A.1 & A.2), process flow (Appendix A.3 & A.4) or document/information flow (Appendix A.5 & A.6). The flow of documentation was also established, as documentation is just as important in HACCP as it is in risk management (Manning, 2013).

The developed PFD was used as a risk identification technique, as Berg (2010) established process mapping as a valuable method for risk identification. The PFD created from the HACCP plan was used as a base and any deviation from the PFD, and thus the HACCP plan, was identified as a non-conformance and effectively, a risk. The development of a PFD also facilitated the identification of improvement opportunities. The PFD was used, together with the direct observation technique, to assess whether the production line staff were implementing the prescribed procedures of HACCP. The developed PFD was effectively validated by the direct observation technique. The validation procedure will be discussed in more detail in the *Direct Observation* section. Furthermore, the PFD of the catfish processing line formed the foundation of the material flow analysis of the CPUT-based pilot plant and the operations at Le Cap Foods, as the PFD indicates where and to what degree resources are consumed on the production line and for what purpose. This aspect of the PFD will be discussed in further detail in the *Material Flow Analysis* section.

The PFD established a context for the risk management framework of the pilot plant and enabled the identification of risks concerning employee conformance to HACCP and GMPs. A qualitative risk assessment was conducted by using the risk matrix presented in Figure 3.1. In addition, the PFD initiated the material flow analysis of the facility. The development of the PFD, therefore, assisted with risk identification and control in the facility, thereby contributing to the achievement of the second research objective.

Table 3.1 The risk matrix used for qualitative risk assessment

		IMPACT				
		Trivial	**Minor**	**Moderate**	**Major**	**Extreme**
PROBABILITY	**Rare**	Low	Low	Low	Medium	Medium
	Unlikely	Low	Low	Medium	Medium	Medium
	Moderate	Low	Medium	Medium	Medium	High
	Likely	Medium	Medium	Medium	High	High
	Very likely	Medium	Medium	High	High	High

3.3.4 Direct Observation

The developed PFD for the catfish processing operation at the CPUT-based pilot plant and Le Cap Foods was validated by using the direct observation technique. The observation was done in the form of a walk-through audit in the CPUT pilot plant as well as at Le Cap Foods. The employees on the processing line of the CPUT-based pilot plant were observed at random during different production runs and at different times of the day. The occasions selected for direct observation were also randomly selected in order to get a general impression of the performance of the employees. This was done in accordance with the random sampling technique. Furthermore, observation was conducted without interfering or interacting with the employee being observed, as this is the standard technique for direct observation according to Zikmund *et al*. (2013:260).

The physical actions of the employees on the production line were observed in order to determine if employees operate according to the prescribed procedures in the HACCP plan for the CPUT-based pilot plant and Le Cap Foods, and essentially, to validate the developed PFD. Any deviations from the PFD was discussed with the supervisors to determine if the deviation should be accepted or if it is, in fact, a non-conformance. Repetitive non-conformances were regarded as risks in the facility and control measures were proposed.

Furthermore, each workstation in the production line was individually observed to establish a performance standard for the employees. The performance standard will be discussed further in the *Time Study* section. The visual information regarding the performance of the employees was validated by the information obtained from employees during the interviews regarding their motivation and knowledge of food safety practices. In addition, areas in which frequent delays were observed were identified as production areas that needed improvement. The source of the problem was identified and improvement strategies were suggested. The direct observation technique provided a method for identifying risks in the facility and therefore contributed to the achievement of the second research objective. A qualitative risk assessment was conducted on the indented risks with the use of the risk matrix in Table 3.1.

3.3.5 Questionnaires

Self-completion, structured questionnaires were administered to production line employees working in the CPUT-based pilot plant as a means to determine the human behavioural factors that are potentially inhibiting the effective implementation of HACCP and GMPs in the facility.

The questionnaire used in this study consisted of 20 questions. These questions were divided into four different groups to cover all the critical factors that could potentially inhibit the performance of HACCP. The first group included five questions that related to the knowledge employees have concerning the food safety systems, specifically in the CPUT-based pilot plant of the catfish processing operation. One of the questions focussed on the CCP that was identified in the factory. Other topics related to general hygiene principles, corrective action procedures and processing parameters in the factory. All of the questions had predetermined answers from which one could be chosen. The degree to which employees were trained on food safety issues in the catfish processing plant could be determined through their choice of answers.

The next five questions focused on the attitude of employees towards implementing food safety systems. The questions tested whether the employees understood the benefits and the importance of implementing the systems. For this group of questions, respondents were asked to answer on a five-point Likert-scale (1 → 5: strongly disagree, disagree, not sure, agree, strongly agree). The same rating scale was used for the two remaining groups. The third group also consisted of five questions. These questions targeted the opinion of employees towards their supervisors. The aim was to determine the commitment of managers towards their staff and the food safety system. The final five questions focussed on the general perceptions of employees towards their working environment, which included questions regarding their co-workers. The layout of the questionnaire is presented in Appendix B.

The answers regarding the employee's knowledge of food safety systems in the catfish processing plant (questions 1 to 5), were compared to the HACCP plan of the CPUT-based pilot plant. The results obtained for these questions were discussed in an argumentative form. In contrast to this, questions that involved the Likert-scale ranking (questions 6 to 20) were analysed by converting the ranks to scores.

Each questionnaire administered to a production line employee was followed by an interview. Thus, respondents were able to ask for assistance while completing the questionnaire. Random sampling was employed for the selection of participants in an attempt to avoid the selection of a biased sample and to reduce the chance of sampling error. Employees were randomly approached during a production break where they were invited to take part in the study. The only prerequisite was that the participants be full-time employees of BKT. The population size of this study was 18 people. Questionnaires were administered to a sample of 10 employees, thus more than 50% of the employees participated in the study.

The quantitative results obtained from the questionnaires were supported by the qualitative information obtained from the interviews. This will be discussed in more detail in the *Qualitative Interviews* section. Risks related to the degree to which the production line employees implement HACCP was identified by the data obtained from the questionnaires and a qualitative risk assessment was conducted with the use of the risk matrix in Table 3.1. This research method therefore assisted with achieving the second research objective.

3.3.6 Qualitative Interviews

Semi-structured interviews were conducted with both the production line employees as well as the managers and supervisors of the catfish processing pilot plant at CPUT. Semi-structured interviews were used in both cases, as the opinions and perceptions of the interviewees were essential to the research. Employees working on the production line were chosen at random to participate in the study and were invited personally. Interviews were conducted individually in order to avoid others from influencing their opinion and views, as some of the questions related to their co-workers and supervisors. The interviews with the production line employees were approximately ten minutes in duration. All of the supervisors and managers involved at the production line of the CPUT-based pilot plant (n=4) were personally invited to participate in the study, as the number of managers is significantly less than that of the production line workers. The interviews with the managers were more in-depth as managers tend to be more knowledgeable and experienced in food systems and safety issues and this took approximately fifteen minutes each.

Furthermore, a voice recorder was used to record interviews with both production line employees and supervisors as this technique allows a more thorough examination of the interview and enables the researcher to re-examine the recording (Bryman & Bell, 2014:231). The voice recorder also enabled the researcher to engage with the interviewee on a higher level, as opposed to making notes on a regular basis and losing eye contact with the individual.

As mentioned, the interviews with the production line employees were used as a supportive method to the questionnaires. According to Harris and Brown (2010), this method is often used in mixed method studies, however, it is emphasized that it is most effective when the content of two methods align. Harris and Brown (2010) therefore suggest that the questionnaires and interview prompts be similar; both data collections should occur in a short interval of time and the object of interest should be defined well. Thus, prompts used in the interviews also focussed on the four different factors that may influence the effective implementation of HACCP: education and training, attitude, managerial commitment and the working environment. A list of questions on these topics was compiled and served as an interview guide, however, a natural flow of conversation was encouraged.

The qualitative information obtained from the interviews was analysed through a coding process. The grounded theory framework presented by Bryman and Bell (2011:344) was used to analyse the qualitative data obtained from the interviews. The answers were categorised according to the above-mentioned topics and were linked to the question groups formed in the questionnaire. The aim was to identify similarities between the information obtained from the interviews and the data obtained from the questionnaires, as similarities would in effect validate the results obtained from the questionnaires. Identified risks were categorised according to their origin, which would be from lack of training, poor attitude, inefficient managerial commitment or an unsupportive working environment. This method, together with the questionnaires, therefore enabled the identification of behavioural risks in the production line workforce, and thus assisted with achieving the second research objective.

Furthermore, the interviews with the supervisors focussed on the status of the FSMS in the CPUT-based pilot plant and what, in the opinion of the supervisors, is hindering the operation from achieving its food safety and quality goals. A few topics related to factors that inhibit the implementation of HACCP was used to create an interview guide. Some of the topics included the educational background of the supervisor, the commitment of management towards implementing an FSMS, resource availability, motivation for implementing FSMS, and finally, food safety goals of the company. The opinion of supervisors with regard to perceived risk in the factory was also discussed.

The qualitative information obtained from the managers and supervisors was analysed through a coding process. The interviews were transcribed and reviewed to obtain a general idea of the content. The response of the managers and supervisors were categorised according to the discussed themes that were raised in the interview, and similar answers were grouped together. Notes were made of unique answers as well. Arguments were made concerning the degree of risk posed by the supervisors and managers with regard to food safety implementation. More importantly, recommendations were made with regard to areas that require improvement. Thus, the interviews supported the risk identification procedure and assisted with achieving the second objective of this study. Identified risks were qualitatively assessed by using the risk matrix in Table 3.1.

3.3.7 Material-Flow Analysis

The aim of conducting a material flow analysis in the catfish processing plant was to quantify the incoming and outgoing goods of the production process in order to obtain information regarding the production yield as well as the amount of waste produced by the catfish processing pilot plant at CPUT and Le Cap Foods. This information assisted with the identification of risks and improvement opportunities with regard to productivity and waste production.

During processing, certain parts of the whole catfish are segregated into different production lines. The flow of the fish components along the catfish processing line at CPUT was analysed by considering the inputs and outputs of each activity in the production line. The validated PFD of the catfish processing line provided a foundation for the material flow analysis. Processes that involved material leaving the processing line were identified as system boundaries.

The data for the mass flows were physically obtained from the production site at CPUT and Le Cap Foods. The catfish samples were chosen at random and each fish was weighed on a calibrated scale before entering the production line. The catfish entered the pre-cooker rinser, the hot water bath, and the pressurised water spray, after which random samples were weighed again. The weight difference of the fish between the two stages was taken as the weight of the slime. Next, the fish entered the evisceration line where it was manually gutted and headed. The gut and gall were weighed separate from the fat, liver, and testes/eggs. The head, lungs, and jaw were weighed together, and the tail fin was weighed separate. Thereafter, the remaining body of the fish was weighed. Random samples were chosen for each recording. The remaining body of the fish entered the filleting line at which the side fins were removed and weighed. The remainder of the fish was processed into two fillets and the back-bone. The two fillets were weighed separate from the back-bone. The fillets were taken to the skinning station and the skin was removed. The two skinned fillets were weighed together while the skin was weighed separate. The fillets were transferred to the bowl cutter and each minced batch was weighed. The product was weighed in bulk at stations that involved mincing, such as the bowl cutter, the 6mm mincer, and the Comitrol. Finally, the product was weighed in bulk at the mixing station and was weighed again after it had been mixed with other ingredients. As mentioned, random sampling was employed for the material-flow analysis in order to reduce the chance of sampling error. A sample size of at least 30 was selected at each point in the production line in order to allow the sample distribution to strive towards a Normal Distribution.

The data obtained for the material flow analysis were used to establish the average mass of each component at different production stages. The yield of each component was calculated as follows:

$$PY_{component\ i} = \frac{M_{component\ i}}{M_{whole\ fish}} \quad (1)$$

Where

$PY_{component\ i}$ = *Production yield of component i [w/w %]*

$M_{component\ i}$ = *Average mass of component i [kg]*

$M_{Whole\ fish}$ =*Average mass of whole fish prior to processing [kg]*

In order to calculate the theoretical production yield per batch, the theoretical yield of all the components ($PY_{component\ i}$) that form part of the product in question, were summed. The calculation of the theoretical production yields (percentage) allowed the calculation of the theoretical mass of a product or component to be obtained if a batch was processed. The following equation was used to calculate the theoretical mass obtainable for a component or product during batch processing:

$$M_{Product\ j\ or\ component\ i} = \sum_{i=1}^{n} PY_{component\ i} \times BS \quad (2)$$

Where

$M_{Product\ j\ or\ component\ i}$ = *Mass of product j or component i obtained from a batch [kg]*

$PY_{component\ i}$ = *Production yield of component i [w/w %]*

BS = *Batch size of harvested fish [kg]*

Furthermore, the mass of the other ingredients (where applicable) were added to the weight of product to calculate the final theoretical yield. The overall theoretical production yield was obtained by adding the production yield values ($PY_{Product\ i}$) of all the valuable products together. The theoretical yield takes into account the wanted losses such as the blood, slime, gut, and gall, but it does not compensate for variable losses on the production line. Therefore, actual processing data was obtained from the company in order to compare it to the theoretical yields. In addition, unwanted losses were determined at each step in the production line by determining the mass of the product before and after the processing step. Arguments were made for any discrepancies between theoretical and actual data and risks were identified. Risks were also identified concerning the wanted and unwanted waste produced on the production line. The material flow analysis of the catfish processing line contributed to the achievement of the second research objective. Finally, the methodology and results for this section were validated by presenting the data to experts in the field of operations management.

3.3.8 Time Study

A time study was conducted at the CPUT-based pilot plant and at Le Cap Foods upon the completion of the PFD. Time study forms were created as prescribed by Freivalds and Niebel (2009:420). Each processing step in the PFD was treated as a single element in the time study. A standard start and finishing point was set for each element, after which the task time or the observed time (OT) was obtained. A performance rating (R) was given to each observed employee in order to obtain a normal time (NT) rating for completing the task. As mentioned in the *Direct Observation* section, a performance standard was established for each processing step by observing various production runs. The performance standard was not accompanied by a physical benchmark, as it is suggested by Freivalds and Niebel (2009:440); however, a good indication of the speed and ability of an average employee in the facility was obtained. According to Freivalds and Niebel (2009:425), one performance rating can be given to the entire study. Nevertheless, the production steps of the catfish processing line are long and diverse; thus, individual performance ratings were preferred. The normal time (NT) of each task was calculated by using the following equation from Freivalds and Niebel (2009:425):

$$NT_i = OT_i \times (\frac{R}{100}) \tag{3}$$

Where

NT = Normal time for element i [min]

OT = Observed time for element i [min]

R = Performance rating (%) given to the employee

The number of observations per element required to obtain valid time study results was determined by the method proposed by Freivalds and Niebel (2009:423). A pilot test was performed where the average and standard deviation of time ratings were obtained for each element in the production line, and a confidence level was selected for the number of observations. The following calculation was used to determine the required number of observations per element (Freivalds and Niebel, 2009:424):

$$n = \left(\frac{s \times t}{\alpha \times \bar{x}}\right)^2 \tag{4}$$

Where

n= The number of cycles to be observed

s= Standard deviation of the time ratings for the pilot test

t= Obtained from the t Distribution (degrees of freedom;α)

α= $(1 - \frac{confidence\ interval}{100})$

$\bar{x}$= *Mean of the time ratings obtained from the pilot test*

Time allowances were approximated for every step (element) in the production line by making use of the allowance factors given in the Work Study Textbook of the International Labour Office (ILO) of Switzerland (1992:491-498). Fixed allowances, which included personal needs and basic fatigue, as well as variable allowances, were considered as the working conditions in the processing plant are different to that of an office environment. As proposed by the ILO (1992:491-498), the severity of each type of strain was considered for all workstations on the production line. Points were allocated to each workstation for each type of strain, depending on the degree of strain imposed by the performed tasks. The allocated points were summed for each workstation where finally it was converted to an allowance factor by using the conversion table provided by the ILO (1992:497-498). The allowance factor obtained from the conversion table for each workstation was added to the mean NT of the same workstation. The allowance factors provided in the table included allowance factors for basic fatigue and personal needs (fixed allowances). Therefore, according to the points-conversion table (ILO, 1992:497-498), the minimum allowance that could be allocated to any station was 10%. The standard time (ST) of each task was calculated by using the following equation from Freivalds and Niebel (2009:425):

$$ST_i = NT_i \times (1 + allowance) \tag{5}$$

Where

ST_i= *Standard time for element i [min]*

NT_i= *Mean normal time for element i [min]*

The ST time obtained from adding all the time factors to the NT signified the time allowed for a competent worker to perform the given task while working at a normal rate. In order for the ST ratings to be used for the line balancing and the value chain cost analysis, the standard time was converted to a standard time per kilogram processed for each activity. The average weight for the component or batch at each processing step, obtained from the *Material Mass Flow analysis*, was used to determine the standard time per kilogram processed in the following equation:

$$ST\ per\ kg\ processed = \frac{ST_i}{M_i} \tag{6}$$

Where

ST_i = Standard time for element i [min]

M_j = Average mass of component at element i (or batch of components) [kg]

The methodology in this section and the results obtained were validated by experts in the field of operations management. Furthermore, the ST rates were used to balance the resources on the production line and for estimating the direct labour costs for each activity for the value chain cost analysis. This will be discussed in more detail in the *Line Balancing* section and the *Value Chain Modelling* section, respectively.

3.3.9 Line Balancing

The productivity of the catfish processing operation at CPUT and Le Cap Foods was addressed by using a Line Balancing (LB) approach. This approach was chosen as, according to Chueprasert and Ongkunaruk (2015), it is an effective tool that reduces labour cost and improves the productivity of manual operations.

Each processing step in the production line, as identified by the PFD, that required direct labour was identified as a workstation, including the in-house transport activities. Microsoft Excel (2010), a spreadsheet programme, was used to create an LB model. Parallel lines in the production facility were identified and different LB models were created for each individual line.

The ST per kilogram and the number of employees at each workstation were inserted into the model. The cycle time per employee per machine for each workstation was calculated as follows:

$$CT_i = \frac{ST_i}{n_{Ei}} \tag{7}$$

Where

CT_i = Cycle time per employee at workstation i [min.kg^{-1}]

ST_i = Standard time of workstation i [min.kg^{-1}]

n_{Ei} = Number of employees at workstation i

The production line efficiency (E) was calculated by determining the total cycle time per employee for all workstations (TT), as well as the bottleneck (B) of the production line. The bottleneck was identified as the workstation with the longest cycle time per employee. The production line efficiency was calculated as follows:

$$E = \frac{100 \times TT}{n_W \times B} \tag{8}$$

Where

E = Line efficiency [%]

TT = Total cycle time per employee for the whole production line [min.kg^{-1}]

n_W = Number of workstations in the production line

B = Bottleneck cycle time [min.kg^{-1}]

The takt time (T) of the production line, also referred to as the theoretical maximum cycle time, was used to evaluate the capacity utilization of the production line operations. The takt time as well as the adjusted takt time (T_A) of the processing line at the CPUT based pilot plant and Le Cap Foods, was calculated as follows:

$$T = \frac{C}{D} \tag{9}$$

$$T_A = T \times (1 - M) \tag{10}$$

Where

T = Takt time of production line [min.kg^{-1}]

C = Net production time [min]

D = Customer demand per period [kg]

T_A = Adjusted takt time [min.kg^{-1}]

M = Machine breakdown allowance

The method discussed above was used to analyse the productivity of the current production line, after which inefficiencies and risks were identified. Process improvements were proposed using LB as well as Eliminate, Combine, Rearrange, and Simplify (ECRS) concepts. The aim of implementing these techniques was to determine how the line efficiency of the catfish processing line could be improved theoretically by varying resources and workstations. As part of the LB concepts, resources were allocated to the identified bottleneck to increase its capacity and to reduce the waiting time on the production line. The productivity of the production line was further improved by combining tasks and as a result, decreasing workstations. Tasks were also simplified and rearranged to decrease the waiting time on the production line.

A sensitivity analysis was conducted by applying three different LB approaches to the LB model. The effect of different inputs was evaluated in terms of the resulting cycle time and efficiency of the production line. The benefits, as well as the risks associated with each LB outcome, were identified. Ultimately, LB of the production lines at both facilities assisted with the achievement of the second and third research objective of this study, as risks and control measures related to the productivity of the operation were identified and proposed, and a sensitivity analysis was conducted on the model. The methodology used in this section and the results obtained were validated by presenting the information to experts in the field of operations management.

3.3.10. Value Chain Modelling

The value chain of the processing operations at both CPUT and Le Cap was modelled in order to determine the monetary value added to the product at every step of the production line and ultimately, to determine the financial risk of certain events in the facility.

An Activity-Based Costing (ABC) approach was used to determine the production cost of each processing step. This method was chosen as it allows the transformation of resource expenses into the cost of activities performed in a company, and ultimately the total production cost attributed to a specific product. Firstly, the work activities were identified. Activities were chosen while considering the aim of the value chain analysis: to determine the monetary value added to the product at each step of the production line. Therefore, all the activities directly related to the production of the minced fish were identified. These activities are similar to the workstations identified in the *line balancing* section.

As mentioned in the *Literature Review*, a traditional ABC analysis traces direct production costs and overhead costs back to a product by establishing the elements of cost associated with each identified activity. However, only the direct production costs were considered for the value chain modelling of the pilot plant, as the overhead costs for the impermanent production facilities would not have been an accurate representation of the actual overhead cost incurred by the catfish processing operations.

Furthermore, the elements of costs were identified as the resources consumed by the activities. The resources were grouped according to different cost pools and each cost pool was allocated a cost driver. Firstly, a "Labour" cost pool was identified for all activities in the production line. The cost driver for labour was established as the total time (min.kg^{-1}) spent by an employee to perform each activity. The total time was taken as the ST rating obtained from the time study. The labour cost per minute was determined by consulting the general ledger of the company. The labour rate per minute was determined by taking into account the net working hours of the employees. Evidently, the labour cost associated with each identified activity in the production line was calculated as:

$$Direct\ labour\ cost\ per\ activity = n_{Ei} \times ST_i \times C_L \tag{11}$$

Where

n_{Ei}= *The number of employees at workstation i*

ST_i= *The standard time rating of workstation i [min.kg^{-1}]*

C_L= *Rate of direct labour per minute [ZAR]*

Another resource cost pool was identified as "materials", which included the direct material required to complete an activity on the production line. The cost driver for materials was identified as the amount of material needed, per unit or kilogram, to perform the activity. Thus, the material cost of each activity was determined by multiplying the cost of the material per kg or unit, with the total amount of material spent on the activity.

The sum of the direct labour cost and the material cost per activity was obtained to determine the total direct cost for each activity. The weight of product processed at each step was also considered, as it will have an effect on the activity time and ultimately, the cost of the activity. The material flow data was used to determine the mass of the product, or the batch, at each workstation down the production line and the activity cost was calculated according to the batch size (per kg). The cumulative cost of each activity was ultimately used to obtain the total direct cost of the production process. The steps taken to determine the monetary value added to the product at each step in the production line is summarised in Figure 3.1.

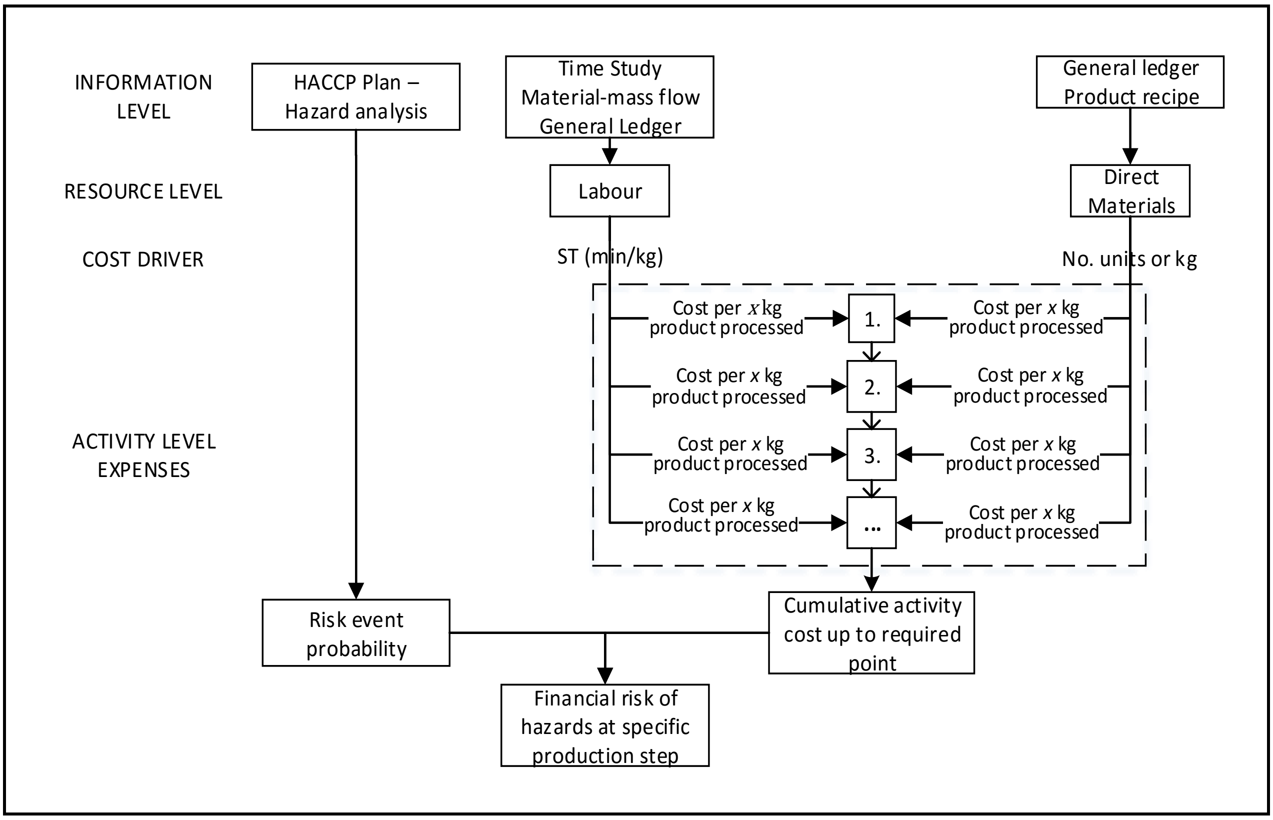

Figure 3.1 Activity-Based Costing model applied in the Value Chain Analysis of the catfish processing line.

Once the direct production cost was calculated for each step, the financial risk could be calculated. The direct production cost was used to estimate the financial risk rather than the selling value of the product or batch, as a profit margin has not yet been established for the fish mince. However, once the company has established a solid market for their product and profitability becomes a significant performance factor, the financial risk could be estimated by using the selling value of the product or batch.

Figure 3.1 illustrates that the HACCP plan was consulted to determine the probability of a hazard occurring on the production line. The HACCP plan contained the results of the hazard analysis conducted on the production line during the development of the HACCP system. The results of the hazard analysis were used to determine the financial risk of physical, chemical, or biological hazards occurring on the processing line. The results obtained from the risk matrix in the HACCP plan was converted to a percentage rating in order to calculate the expected monetary value of the risk. Table 3.2 presents the conversion table used to estimate the risk probability from the given risk matrix.

Table 3.2 Conversion table for estimating risk event probabilities

Likelihood of occurrence from HACCP plan	**Probability of occurrence**
Very small	> 0 - ≤ 0.25
Small	> 0.25 - ≤ 0.5
Average	> 0.5 - ≤ 0.75
Large	> 0.75 - < 1

After which the expected monetary value (*EMV*) of the identified risks were calculated as:

$$EMV = (production\ cost\ up\ to\ specific\ point)\ x\ (probability\ of\ hazard\ occurring(\%)) \quad (12)$$

The value chain model was validated by interviewing an expert in the field of food production. The aim of the interview was to establish if the proposed model is practical and appropriate for the company in question. The suitability of the model to similar production facilities was also discussed. Furthermore, a sensitivity analysis was conducted on the model by changing input values such as batch size and raw material cost and monitoring the change in production cost and financial risk. The aim was to identify which parameters will affect the cost of production the most and which processing points pose the greatest financial risk. The value chain model, therefore, assisted with achieving the second and third research objective of this study.

3.4 Statistical Approach

The data obtained from the questionnaires were analysed by using the Statistical Package for the Social Sciences (SPSS) (version 22). The questionnaire was pre-coded, thus each answer was linked to a value. The data obtained from the first question can be considered dichotomous variables, as only two categories exist. Data from the following four questions (questions 2 to 5) can be considered nominal variables as the questions contain categories that cannot be ranked. Thus, the data from the first five questions was analysed by determining the frequency and the mode. However, the data from questions 6 to 20 contain interval variables, as the answer categories are ranked and have identical distances between the categories (Bryman & Bell, 2011:313). The data of these questions were analysed through descriptive statistical methods, specifically by calculating the mean of the answers for each question, as well as the SD of the data.

The data obtained from the material mass flow study was analysed by using the SPSS (version 22). The mean mass of the product component at every production step was calculated, as well as the standard deviation of the data obtained for each component. The proportion of each component in relation to the whole fish, prior to processing, was calculated by using the mean values obtained.

3.5 Summary

In this chapter, the methodologies and research techniques applied in this study were discussed. Figure 3.2 illustrates the proposed risk management framework for the catfish processing pilot plant, where the critical steps are presented in blue. Initially, a context was established for the risk management framework by investigating food safety documentation. Once the context was established, the human resources, the processes, as well as the costs involved in the catfish processing line were analysed in order to identify risks. Upon the identification of risks, the risks were further analysed by establishing the probability of the event occurring as well as severity of the event in terms of money, time and product quality. Finally, appropriate control strategies were proposed for the identified risks by considering the constraints of the facility.

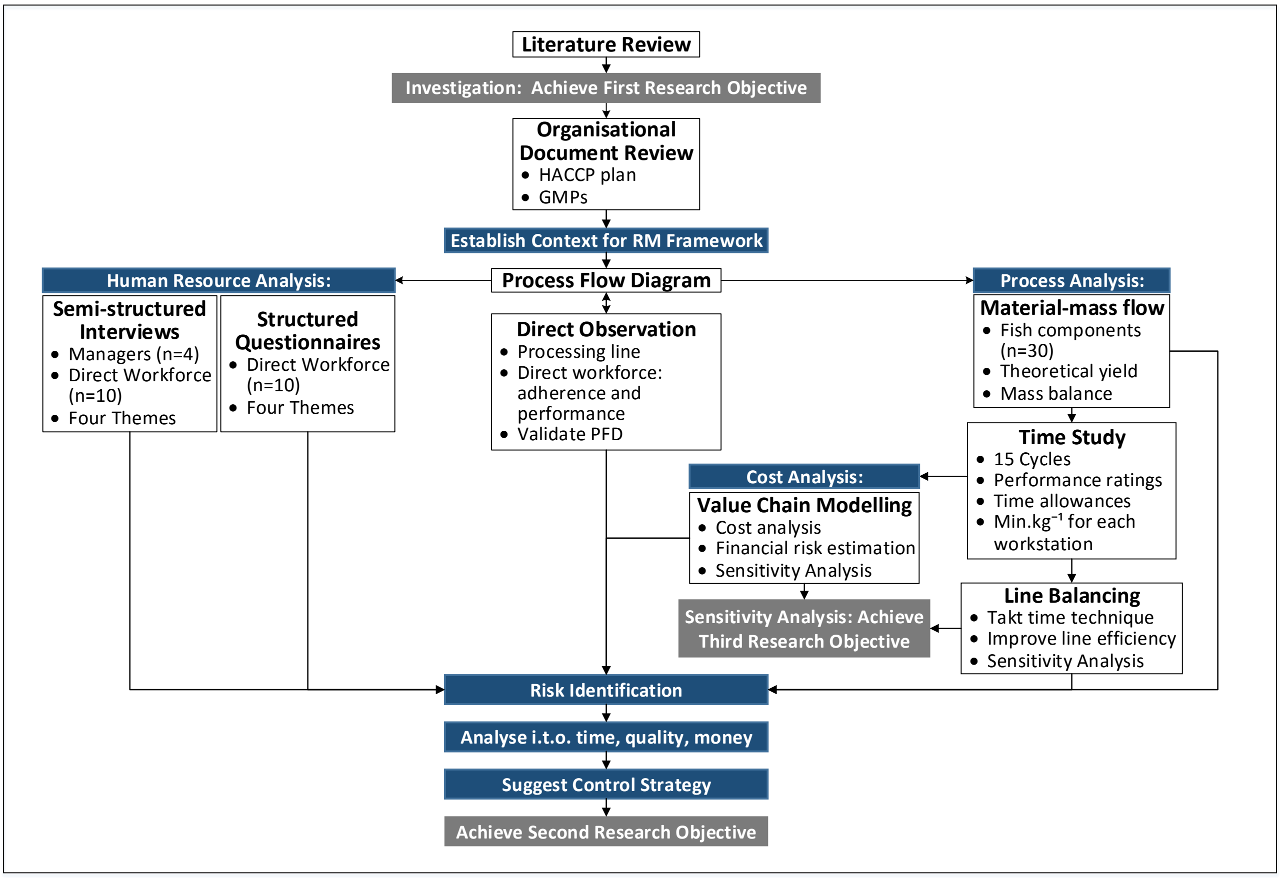

Figure 3.2 The critical points of the risk management framework and the achievement of research objectives.

4. RESULTS AND DISCUSSION

In this chapter, the potential impact of the identified risks with regard to time, money and quality is discussed, and control strategies are proposed for each of the identified risks. Furthermore, a sensitivity analysis is conducted to investigate the influence of various production parameters on the proposed risk management framework. The focus of the fourth chapter is therefore to answer the second, as well as the third research objective of this study, which involves the suggestion of risk control strategies and the implementation of a sensitivity analysis.

4.1 The catfish processing line

The development of the Process Flow Diagram (PFD), as well as the direct observation technique, allowed an in-depth study of the process flow, product flow, and information flow of the production lines at both CPUT and Le Cap Foods. A foundation for the risk management framework was set by studying the internal operations of both facilities. The following sections will discuss the processing procedures that take place at the CPUT-based pilot plant and at Le Cap Foods facility.

4.1.1. Processing Line: CPUT-based Pilot Plant

The process flow at the CPUT-based pilot plant is presented in Appendix A.3. The processing operation is initiated with the receiving of fresh catfish on ice. The fish is harvested on the farm in Graaff-Reinet, after which it is loaded and transported (on the same day) in a refrigerated truck to the Cape Peninsula University of Technology (CPUT) in Bellville, Cape Town. Approximately 1000 kg of fish, each weighing between 1 kg and 1.5 kg (depending on the end-product use), is harvested at a time and BKT is given two days to process the fish at CPUT. Once received, the fish is placed directly into the cold store, which is kept between 0^{o}C and 4^{o}C. Single crates of the whole fish are taken to the production line once all the pre-process cleaning and inspections are complete. The weight of each crate of fish is recorded before it is processed.

The first processing step is the pre-cooker rinser. This step is important for removing excess slime from the skin of the fish. The presence of slime in the minced fish will decrease the quality of the product. The operator at this station feeds the fish into the rinser and aims to maintain a continuous flow of product in order to avoid product build-up at following stations. Once the fish is cleaned from excess slime, it is dropped into a hot water bath. It is important that the fish is fully submerged under the 95^{o}C-heated water for seven seconds. This allows the remaining slime on the fish to coagulate. The operator at this workstation ensures that the fish is fully submerged under the water by pressing a metal rod down on the conveyor belt that takes the product through the bath. The operator also ensures that the slime is sufficiently coagulated before the product moves to the next station.

The conveyor belt carries the product to the next step, the pressurised water spray. This production step is necessary to remove all possible traces of slime from the exterior of the fish. Production delays will occur if the slime is not removed sufficiently, as the personnel working at the dissecting workstation will have to clean the remaining slime before they can continue with their normal tasks. The operator at the water spray station, therefore, avoids this delay by ensuring that the product is sufficiently cleaned once it exits the water spray.

After the pressurised water spray process, the fish is eviscerated. This production step consists of various workstations and several operators. Once the product is obtained from the conveyor belt, it is clamped to an evisceration board and gutted. The blood, guts, and gall bladder are placed in a dedicated waste container, while the fat, liver, and testes/eggs are placed in a container for the main product. The back fin as well as the head, lungs and gills are placed on the conveyor belt leading to the pet food mincing station, which is referred to as line 2 in this study. It is important to note that the pet food production operations beyond the current production line will not be discussed in this study. Whole, gutted fish can also be produced at the evisceration step, where the guts and organs are removed, but not the head. The processing of this product, therefore, stops at the evisceration step. At this stage, the company only produces the whole, gutted fish on request and therefore the processing steps of this product is not included in the official HACCP plan of the operations. The focus of this study, thus, remains on the fish mince produced at the CPUT-based pilot plant. Furthermore, the remaining part of the fish is placed on the main conveyor belt (line 1) once the operator is certain that the product is clean from fish and foreign objects such as blood and guts. The conveyor belt then delivers the product to the filleting workstations.

The filleting production step, similar to the evisceration step, consists of various workstations and operators. The operator firstly removes both the side fins of the fish and places it on the conveyor belt leading to the main product mincing station, which is referred to as line 3 in this study. The operator then obtains two fillets from the fish, as well as the back-bone. Although both of these components are constituents of the main product, they are placed on different lines. The back-bone is also placed on line 3, together with the side fins, as it requires specific mincing before it can be added to the main product. However, the fillets remain on line 1, as it requires less harsh mechanical processing. The main product, fish mince, is produced from fish that weigh approximately 1 kg, as the bones of the fish have not yet developed into strong and hard structures at this stage. However, other products, of higher value than fish mince, are produced when larger fish (1.2-1.5 kg) are harvested, such as cutlets. A larger fish is able to produce a cutlet as well as two fillets. The fillets can also be sold whole and smoked, and have more value than the minced fish. However, these products are not yet included in the official HACCP plan of the production operations and were therefore not included in this study.

The side fins and back-bone are minced once there is enough product to put through the mincer. An operator is required to feed the mincer; however, the operator assigned to this workstation can be assigned to other workstations as well. Once enough product has been minced, the crate of mince is carried to the Comitrol. The Comitrol is a 1 mm mincer that is essentially used to make a pulp out of the bones and organs by applying incremental shearing. Two operators are assigned to this workstation, as one collects the product from the crate and feeds it to the machine, while the other holds a plastic shield to prevent the product from splattering on the surrounding environment. The minced product obtained from the Comitrol is referred to as “softs” and is placed in the cold store until it has reached a safe processing temperature or until the fillets are also ready for mixing.

In the meantime, production continuous on Line 1. The fillets obtained from the filleting station are taken to the skinning machine. A single operator is required to feed the fillets to the skinner and to do the quality checks after the fillets have been skinned. Fillets are placed through the skinner again if the skin is not removed sufficiently. The skinned fillets are taken to the bowl cutter. The bowl cutter cuts the fillets into small blocks rather than mincing it. The bowl cutter is filled with the fillets and the operator checks the product from time to time to determine whether the correct product size has been reached. The product is placed in a crate and taken to the cold store if the mixing process does not commence immediately or if the product temperature has increased significantly during processing.

The mixing process is conducted once there is enough product to process. The product is mechanically mixed in 100 kg batches at a time, where 60% is the cut fillets, 25% is “softs” and 15% is Hydrated Texturized Vegetable Protein (HTVP), also known as soya mince. Each ingredient is weighed and added to the mixer. Once the operator is satisfied with the product mixture, the industrial mixer is turned on its side and the content is emptied into plastic lugs lined with clear plastic bags. Each crate is weighed and the weight of the product is written on the label. The label also contains the company name, product description, production date and use-by date. The specification states that the product should be further processed within one day of delivery. The crates are placed in the cold store until the product has reached a temperature of between 0˚C and 4˚C, or until it is collected by the contract transporters. The cold storage processing step of the final product is the only CCP identified in the production line at CPUT.

4.1.2. Processing Line: Le Cap Foods

Once the minced fish is received from CPUT at Le Cap Foods, the temperature is checked (between 0^0C and 4^0C) to and the product is placed in the cold store (kept between 0^0C and 4^0C) until production commences. The fish mince is either kept plain or it is minced with a variety of sauces. The sauce was considered an added ingredient in the product and the production process of the sauce was not included in this study.

The production operation is initiated with the weighing of raw materials in the mixing area. The raw fish mince is mixed with maize, a thickener, and salt in a mechanical mixer. The amount of fish used per batch depends on the recipe issued by the production manager. The mixed product is placed into 25 kg plastic containers and carried to the filling area. The filling process is automated; however, manual operations are preferred for the packaging of small pouches, as the product is not heavy enough to fall through the funnel and into the pouch.

In the automated filling process, manual labour is still required to fill measuring cups with the product before it enters the line. Operators weigh the appropriate amount of product in a container, which depends on the pouch size, and pass it to another operator that empties the container into the measuring cups that stay on the filling line. On the other end of the line, an operator feeds retort pouches to the machine. The filling machine opens the pouch by making use of a gas flush and the sauce is poured into the pouch from the sauce tank (if the product requires sauce). The filling machine empties the measuring cup filled with the minced fish, into a funnel that ultimately guides the product into the opened pouch. The pouch is then heat-sealed on the filling machine after which it is issued to an operator at the receiving end.

The operations on the manual filling line are similar; however, more personnel are required. Operators manually open the pouch and prepare it for filling. At the next station, operators weigh the required amount of product and manually pour it into the pouch. The same is done for the sauce if it is required. Before the pouch is sealed, it is manually cleaned around the top area to prepare it for the sealing process. Once the pouch is cleaned, it is placed in the vacuum sealer. The vacuum seal is only used to reduce the amount of air in the pouch, which essentially reduces the chance of microbial growth. The pouch is finally heat-sealed at 175^0C.

All the sealed pouches are placed on the retort trolley until the ten layers of the trolley are filled. The trolleys are placed in the cold store if further processing does not commence immediately, alternately, the trolleys are placed in the retort room. Once all the mince is packaged, the trolleys are placed in the retort to cook at 121^0C at 2 Bar for 40 to 78 minutes, depending on the size of the pouch. The retort process is the only CCP identified on the catfish processing line at Le Cap Foods. The product is left to cool until a safe temperature is reached.

Samples are taken from each retort batch for incubation at both 37^0C and 55^0C. The samples are incubated for two weeks, after which microbiological analysis is conducted to confirm that it is safe for human consumption. The finished products are stored in the warehouse until the microbiological results are obtained. Once the product is officially deemed safe for consumption, it is distributed to the customers. The cooked fish mince has a shelf life of approximately one year.

4.2 Workforce and HACCP implementation

The implementation of HACCP in the CPUT-based pilot plant was investigated. As mentioned in the literature review chapter, a company has the potential to benefit from implementing HACCP as it can lead to higher productivity and lower production costs. However, HACCP has to be introduced and implemented in an effective way in order for the company to realise these benefits. Information was obtained from the permanent employees of Blue Karoo Trust, who are both the direct workforce and the managers. This information was used to determine the degree to which HACCP is implemented in the CPUT-based pilot plant and to establish control strategies for risks related to human resources.

4.2.1 HACCP Training and Knowledge on the Catfish Processing Line

The information obtained from the interviews with the production line employees and the managers, as well as the data obtained from the first section of the questionnaire (Appendix B), were used to investigate the degree to which the food handlers are trained, and to determine their level of knowledge concerning Food Safety Management Systems (FSMS).

4.2.1.1 Results

The information obtained from the interviews with the production line employees indicated that they have received training on the basics of Good Manufacturing Practices (GMPs) in a food-manufacturing environment. All of the employees received an education and training certificate after the completion of a one-year course on Food and Beverage Handling Processes. The course focussed on general food applications, and not fish or catfish specifically. Only 20% of the respondents had additional food safety experience from working at other companies. However, literature suggests that knowledge alone does not lead to positive change in food handling practices (Walker *et al*., 2003), thus the ability of employees to apply their food safety knowledge was investigated, and will be discussed in the next section.

Interviews with the managers revealed that the production line employees have not yet been trained on GMPs specific to the catfish processing operation, neither have they been introduced to the HACCP plan developed for the catfish processing line at CPUT. During the interviews with the managers, it was established that the lack of training on these topics was due to time and financial constraints. This is in accordance with results obtained from the Global Food Safety Training (GFST) survey (Emond, 2016), which stated that approximately 67% of food companies find that scheduling time for training is one of their biggest food safety training challenges.

The first section of the questionnaire (questions 1 to 5) administered to the production line workforce tested the knowledge of employees regarding the food safety systems in the catfish processing pilot plant at CPUT. A majority (80%) of the respondents disagreed with the fact that catfish is a high-risk food product. This is disconcerting, as fish is one of the most vulnerable food products concerning bacterial spoilage due to its biological nature (Huss *et al*., 2000). Similar results within a high-risk food manufacturing company were obtained by Clayton *et al*. (2002), where 95% of employees received training but the majority still believed that their company is working with low risk food items. The ignorance of employees concerning the risk involved in their food handling practices may result in the resistance of change to their current practices. However, during the interviews, employees were asked what could happen if food safety practices are not implemented in the catfish processing facility. Fifty percent of the employees mentioned that it could cause contamination and consumers might become ill, thus indicating that they understand the importance of the food safety principles in the catfish processing plant.

The following question involved temperature monitoring of the product during mechanical processing. The response of the employees on this question indicated that they have been trained on this topic, as all of the participants agreed that it is important to monitor the temperature of the product during processing. However, the reason given for their answers differed among respondents. Twenty percent of employees indicated that temperature monitoring is important for maintaining physical quality of the product, while the remaining 80% said that it is important for preventing microbial spoilage, which is unmistakably more important. However, it is clear that all the employees understand that it is necessary, for whatever reason, to control product temperature during processing.

The question relating to the Critical Control Point (CCP) in the catfish processing pilot plant was answered well, which was unexpected, as it was established that the employees have not yet been trained on the HACCP plan. As previously mentioned, the catfish processing pilot plant has only one CCP - the cold store in which the final minced product is stored. Sixty percent of the respondents chose the correct CCP, once again indicating that the employees understand the importance of temperature control in the catfish processing line. From the remaining results, 30% selected the packaging process as a CCP and 10% selected the evisceration step. Neither of these processing steps qualify as a CCP, as a processing step only becomes a CCP once the probability of the hazard occurring is significant and if the hazard detectability decreases down the production line (Bertolini *et al*., 2007). Furthermore, several participants asked what the meaning of a "CCP" is while filling in the questionnaires. The poor monitoring and ineffective control of a CCP can cause adverse health effects in the consumer, thus CCP training, for employees at all levels, is critical.

The following question related to basic food hygiene practices in the catfish processing plant. This question aimed to determine which hygiene principle is the highest priority with the employees. More than half (60%) of the respondents indicated that washing their hands after visiting the restroom is the most important. In addition, during the interviews, several production line employees mentioned that personal hygiene is important to them and to their co-workers. The washing of hands is a basic personal hygiene principle in any food factory, thus indicating that employees have been trained on these principles. Furthermore, from the remaining results, 30% indicated that washing their workstation and equipment before taking a break is the most important, whereas 10% indicated that monitoring the butchery temperature is the most important. The latter once again indicates that employees are aware of the importance of temperature control in the catfish processing plant. However, not a single respondent indicated that visual inspection of raw material is the most important. This potentially infers that the employees are more focussed on direct hygienic practices, such as washing hands and cleaning the facility, than they are on monitoring practices. This could be a result of not receiving detailed HACCP training.

The final question of this section tested the type of action employees would take towards a non-conforming product. A majority (70%) of employees would consult their supervisor before making any decisions and the remaining participants (30%) would immediately react to correct the situation. The results indicate that there may be a relatively slow response in critical situations. The self-confidence of employees should be increased by educating them on what exactly to do in these situations.

4.2.1.2 Discussion of Risks Identified and Appropriate Control Strategies

The results obtained from the direct observation technique, document analysis and first section of the questionnaire indicates that the production line employees require training that specifically involves the GMPs and HACCP plan of the catfish processing plant. Research conducted by Howes *et al.* (2006) determined that improper food handling practices contribute to almost 97% of foodborne diseases in the USA. The detection of food safety hazards in products can potentially lead to market access exclusion and irretrievable financial loss, thus having an extreme impact on the company and its customers. However, due to the final minced product undergoing excessive heat treatment, and in effect sterilising the product, the probability of the risk occurring is moderate. The risk level is therefore classified as high (Table 3.1).

Another risk identified relates to product quality. Product quality in terms of the catfish mince refers to the visual appearance & organoleptic standards, as well as the microbiological standards, which are both defined in the HACCP plan of the facility. According to Heymans (2009), product quality is decreased by an abundance of variation in the production process, and variation is usually caused by a lack of skills and knowledge. Thus, production variation can be reduced by training food handlers on the standard procedures of the operation, which are documented in the HACCP plan. Furthermore, results from the GFST survey indicated that almost 80% of food companies identified improved product quality as the most significant benefit experienced by effective employee training (Emond, 2016). Mortimore (2001) also emphasizes that employees at all levels and disciplines of the company should be trained on HACCP, not only the HACCP team leader and the CCP monitors. Training will allow employees to understand their role in the system and their responsibility towards producing a value-added product. The probability of employee performance leading to a poor quality product is moderate and poor quality products would have a moderate impact on the organisation. Evidently, the risk is categorised as a medium risk (Table 3.1).

Both of the risks identified are due to lack of knowledge and education, and can be mitigated by providing employees with proper and appropriate training on GMPs and HACCP specific to the catfish processing plant. Controlling the risk through training will require resources, such as time and money. In addition, providing continuous training to employees will require funding, but the long-term effect on product quality and food safety, and essentially the brand of the organisation, makes this control strategy cost effective. Thorough planning in terms of budgeting and scheduling should be conducted to ensure the availability of resources.
Furthermore, the basic concepts and procedures of the HACCP plan would remain the same once the pilot plant moves to the full-scale facility in Graff-Reinet. Training the employees before moving to the full-scale plant will be more effective, as the employees will have time to become comfortable with the standard procedures. Scaling up from a pilot to a full-scale plant involves a lot of stress and change, thus, conducting

the training before the time will reduce the anxiety and pressure experienced by the employees, as they will have more confidence in their abilities. Furthermore, these employees will be ready to guide and train the new employees starting to work at the facility in Graaff-Reinet.

Although there is a sound correlation between food safety training and employees implementing relevant principles, it should be kept in mind that training does not guarantee the application of food safety practices (Ball *et al.*, 2009). It is therefore suggested that management measure the effectiveness of the training programmes. The effectiveness of training involves two levels: the effect of training on employee level and the effect of training on the organisational level (Seaman, 2010). The effect on individual employees can be determined through observing and monitoring employees during production runs and by administering knowledge tests after a period. The effect on the organisational level can be determined by monitoring customer complaints, product yield and waste, or microbiological test results (Seaman, 2010). Similarly, in the GFST survey (Emond, 2016), almost 70% of food companies admitted to measuring the value of employee training by monitoring product quality.

4.2.2 Degree of HACCP Implementation in the Catfish Processing Line

The information obtained from the direct observation technique, the organisational documents, and interviews were used to determine the degree to which GMPs and HACCP are implemented in the catfish processing pilot plant at CPUT.

4.2.2.1 Results

GMPs consist of various groups of procedures. During the direct observation process, it was evident that only a portion of GMP procedures is conducted by managers and employees in the catfish processing line. According to Shaw (2016), GMPs consist of various process groups including Personnel, Plant and Grounds, Sanitary Operations, Sanitary Facilities and Controls, Equipment and Utensils, Processes and Controls, and finally, Warehousing and Distribution. During the analysis of company documents, it was established that a complete HACCP plan has been developed for the operations at the CPUT-based pilot plant, thus all GMP procedures, policies, and specifications have been documented. This is a major part of becoming GMP compliant and HACCP certified, however, once the procedures are documented, it has to be performed and monitored.

The Personnel section of GMPs is mostly concerned with the development of policies regarding dress code, personal hygiene and general practices in the facility (Shaw, 2016). This has all been covered in the HACCP plan of the operations at CPUT. The Plant and Grounds section involve the maintenance of the facility in which food production occurs (Shaw, 2016). The catfish processing operations occur in the AgriFood Technology Station (AFTS) of CPUT (pilot plant); therefore the technical staff of CPUT ensure that the structure and maintenance of the facility meet the food standard requirements. Furthermore, Sanitary Operations is a critical section, and it was evident during observation that the production line employees succeed in performing these procedures. The employees follow the developed cleaning and sanitation programme in the sense that the facility and equipment are cleaned before and after processing and appropriate cleaning materials are utilised. Record keeping of all activities is important for traceability and for continuous improvement; however, records of cleaning activities are not documented by management. According to Hofmeyr (2009), a major mistake made by companies in the food industry is that they practice prerequisite programs (PRPs) (which include GMPs) without keeping a strict record of it.

The Sanitary Facilities and Controls section of GMPs include programmes such as water testing, adequate plumbing, effective waste removal, hand-washing stations and adequate floor draining (Shaw, 2016). These procedures are also conducted by the AFTS staff and are not a concern for the BKT employees. The following section of GMP procedures, Equipment and Utensils, is carried out by the catfish processing line employees. The equipment used by the employees is specially made for the catfish-processing environment. The cleaning of equipment is also part of this section, and as mentioned previously, the employees clean the equipment as required.

The Processes and Control section of GMPs involve all processes that aim to reduce the probability of food contamination. During observation, it was evident that the catfish processing facility still needs to improve on the implementation of these processes. A Process Control and Product Release form has been developed as part of the HACCP plan, as a means to determine product adherence at each step in the production line. This document is to be completed by supervisors. Once again, procedures such as visual checks, intermediate cold storage and temperature control, are carried out, but the procedures and results are not recorded on the process release form.

The Warehousing and Distribution section of GMPs include storage procedures of the product. The received raw catfish, the work-in-progress product, as well as the final minced product, is stored in the cold store in dedicated lugs at temperatures of 0°C to 4°C. The fish is also transported in refrigeration trucks, which are kept between 0°C and 4°C. Finished products are labelled in order to communicate the details of the product and the storage instructions to the receiver. These procedures are conducted by the employees as prescribed in the Receiving, Inspection, Storage, and Dispatch documents developed for the catfish processing pilot plant. According to the standard procedure, temperature checklists should be kept upon receiving, during processing and at dispatch. However, these checklists are not kept.

As mentioned previously, an official HACCP plan has been developed by an external company for the catfish processing operation at CPUT. However, the managers admitted that the complete HACCP plan has not yet been implemented in the processing line. This can also be presumed from the results discussed above, which indicate that complete GMPs are not fully implemented in the facility.

4.2.2.2 Discussion of Risks Identified and Appropriate Control Strategies

The results obtained from the direct observation technique indicate that employees and managers only partially fulfil the requirements of GMPs. Partial, instead of complete fulfilment is achieved predominantly due to lack of record-keeping. The catfish processing pilot plant has the appropriate food safety documentation in place, but fail to use the documents in the prescribed way. Research conducted by Holt and Henson (2000) found similar results at other small food manufacturing companies. The researchers concluded that record keeping procedures were typically not implemented due to the ignorance of managers concerning the importance of these practices. Record keeping is essential for determining if safety and quality control procedures are implemented correctly, and in effect, enhances the visibility of the quality assurance system.

Record keeping of production processes form a critical part of traceability systems. Documentation and record-keeping ensure the traceability of all development, manufacturing, and testing activities within an organisation (Patel & Chotai, 2011). Traceability can be described as the precise and accurate recording of production processes throughout the supply chain, which aims to facilitate the identification and resolution of food safety and quality issues (Aung & Chang, 2014). The lack of record keeping means that the implemented food safety systems has no creditability and the company has no evidence of compliance in the case of customer complaints, thus leaving the company exposed. Financial risk is therefore identified as well as the risk of poor quality, as quality issues are difficult to monitor without records. Both risks are classified as high risks due to the occurrence being likely and impact being major (Table 3.1).

In order to suggest a control strategy, the constraints of the company are first identified. The managers in the catfish processing pilot plant indicated that financial resources are a major constraint for properly implementing GMPs in terms of record keeping. However, Aung and Chang (2014) suggest that the benefits experienced from an efficient record-keeping system outweigh the cost of implementing it, even for smaller companies. Benefits include improved production flow control, improved quality assurance systems, timeous identification of problems and finally, a reduction in product waste (Aung & Chang, 2014). Simple record-keeping methods such as paper trails can be used instead of digital databases and software systems in order to save costs. Documentation has already been developed by an external company for the production line, which accounts for most of the financial cost.

Effective documentation and record-keeping is the key to GMP compliance (Patel & Chotai, 2011), and GMP compliance, in turn, facilitates the implementation of HACCP. However, HACCP implementation should occur within the constraints of the company. In order to maintain control of the budget, the company can introduce HACCP in phases, which is referred to as a modular approach (Mortimore, 2001). According to literature (Ball *et al*., 2009), gradual implementation of HACCP has a high rate of success, because employees get used to following new procedures. Thus, implementing the correct practices in the pilot plant can be beneficial prior to the facility moving to Graaff-Reinet. A modular approach can also be used for implementing the record-keeping system. For instance, management can start by recording the results of temperature and visual checks, as these activities are already conducted on a regular basis. The aim is to make the HACCP plan operational by exploiting the procedures and systems that are already in place, and by steadily implementing the remaining procedures when possible.

4.2.3 Employee Attitude towards Implementing HACCP

Data obtained from the second section of the questionnaire, as well as information obtained from interviews with the production line employees, were used to determine the attitude of employees towards implementing food safety principles in the catfish processing plant at CPUT.

4.2.3.1 Results

The statistical analysis of the data obtained from the second section of the questionnaire is presented in Table 4.1. As previously mentioned, this section focused on determining the attitude of the production line employees towards implementing food safety principles.

Table 4.1 The standard deviation and mean ratings obtained for the section of the questionnaire, which focused on the attitude of employees toward implementing food safety principles

Question [a]	N [b]	Mean [c]	SD [d]
6. I have to make sure that the food I work with is safe for human consumption.	10	4.8	0.422
7. The implementation of HACCP will have a positive effect on the product and the company.	10	4.9	0.316
8. It is important that I constantly educate myself on food safety.	10	4.8	0.422
9. I think implementing HACCP promotes teamwork.	10	4.7	0.483
10. I have sufficient time to implement food safety principles.	10	4.4	0.516

[a] Complete questionnaire in Appendix B.

[b] Number of respondents.

[c] Mean rankings obtained from the opinions of the respondents. Opinions were ranked from 1 (strongly disagree) to 5 (strongly agree).

[d] SD : Standard Deviation.

A mean rating of 4.8 (Table 4.1) was obtained for question six, indicating that employees feel strongly about the fact that it is their responsibility to ensure the production of safe food. This is corroborated by the interviews, as various employees mentioned that their main priority is to ensure that the food they produce is safe for human consumption. A similar response was observed in question seven (Table 4.1), with a mean rating of 4.9 (SD=0.316). Thus, most of the employees strongly agree that HACCP has a positive effect on the product and the company. Additionally, 70% of employees during the interviews said that they have already experienced a significantly positive change in the facility and in their personal lives due to HACCP. The employees feel that they can transfer their food hygiene knowledge to their homes and children. They also felt that their co-workers are more hygienic since receiving training.

Furthermore, question 9 specifically focused on the influence of HACCP on teamwork. In the questionnaire, 70% of respondents strongly agreed that HACCP promotes teamwork in their facility, resulting in a mean rating of 4.7 (Table 4.1). Corresponding results were obtained during the interviews, as 60% of the interviewees specifically mentioned that the HACCP training has brought them closer as a team. As everyone has received the same training, the employees feel that each team member understands the importance of implementing food safety principles and that all of them are thus working towards the same goal.

Question 8 related to the willingness of staff to undergo continuous food safety training. A mean rating of 4.8 (SD=0.422) was obtained (Table 4.1), indicating that employees strongly agree that they should regularly be educated on food safety practices. The final question of this section aimed to determine whether time is a possible restricting factor to HACCP implementation. A mean rating of 4.4 was obtained (Table 4.1); indicating that employees feel that there is sufficient time to implement food safety principles and that time is not restricting them.

During the interviews, employees were asked whether they think it is necessary to implement food safety principles, including HACCP, in the catfish processing plant. From the responses, 100% of respondents said that it is necessary, but different reasons were furnished. A majority (60%) said it is important for reducing the risk of contamination and avoiding foodborne illnesses, while others said it is important for maintaining product quality.

Employees were also asked to comment on the attitude of their co-workers with regards to implementing food safety systems. All of the respondents said that there is an overall positive attitude towards implementing food safety principles in the catfish processing plant. Many employees (50%) said that the positive attitude comes from understanding, through training, the importance of the system, while others (30%) said that their co-workers have positive attitudes because they are ambitious about getting the catfish product on the shelves. The remaining 20% of the respondents said that the people working on the production line are inherently responsible people and that practicing food safety principles are a second nature.

4.2.3.2 Discussion of Identified Risks and Control Strategies

The overall high ratings for the second section of the questionnaire indicate that there is a positive attitude towards implementing food safety principles among the production line employees in the catfish processing pilot plant at CPUT. It is evident from the results that employees feel responsible towards the safety of the food products and that they prioritise the safety of the consumers above everything. They are also determined to uphold about food safety because they understand the importance of it and they have first-hand experience of the positive effects of these systems. Evidently, minimum resistance to change is expected from the workforce when HACCP is eventually implemented. Future implementation of HACCP and other food safety systems is likely to be embraced by the employees. Employee commitment towards food safety is further reinforced by the fact that they are willing to undergo continuous food safety training. It can, therefore, be said that the employees understand the role of food safety in the overall success of the company, and they are willing to work towards the achievement of company goals.

According to literature (Mortimore, 2000; Mortimore, 2001; Panisello & Quantick, 2001; Fotopoulos *et al*., 2009; Kafetzopoulos & Gotzamani, 2014), commitment of food handlers and a positive attitude towards implementing food safety principles are essential for effective food safety systems and is especially favourable when implementing HACCP into a facility. Therefore, the attitudes and level of commitment of employees working on the catfish processing line does not pose a risk to the safety or quality of the product, but can, in fact, be viewed as a major strength for the company.

4.2.4 Manager and Supervisor Commitment

The questionnaire data, specifically from the third section (questions 11 to 15), as well as information obtained from interviews with the managers and production line workforce, were used to establish the commitment of management towards implementing food safety principles. The results and identified risks are discussed in the following sections.

4.2.4.1 Results

The statistical analysis of the results obtained from the third section of the questionnaire is presented in table 4.2. Overall high mean ratings were obtained, of which the lowest was 3.9 (question 11) and the highest 4.7 (question 15). Question 11 aimed to determine whether supervisors and managers set a good example for the employees working on the production line. A mean rating of 3.9 (SD=0.738) indicates that most employees agree that their supervisors set a good example for them, but that there is some controversy on the topic. More specifically, 30% of the respondents did indicate that they were unsure whether their supervisors and managers are in fact setting a good example. Correlating results were obtained in the interviews. A proportion of 50% said that the supervisors are not always a good example when it comes to implementing basic food hygiene principles, but that they otherwise have good leadership skills. It was established that the employees have more respect and appreciation for their managers than they do for their supervisors, as the managers have more experience working with people and tend to have a wider knowledge of food safety.

Table 4.2 The standard deviation and mean ratings obtained for the section of the questionnaire, which focused on the attitude and commitment of supervisors and managers

Question [a]	**N** [b]	**Mean** [c]	**SD** [d]
11. The supervisors set a good example for the operators concerning hygiene and food safety practices.	10	3.9	0.738
12. When I have a suggestion or comment concerning food safety and hygiene, I can talk to my supervisor about it.	10	4.0	0.943
13. My supervisors communicate regularly with all operators about hygiene and food safety.	10	4.5	0.707
14. It is clear that my supervisors take hygiene and food safety very seriously.	10	4.6	0.699
15. My supervisors handle food safety issues in a constructive and respectful way.	10	4.7	0.483

[a] Complete questionnaire in Appendix B.

[b] Number of respondents.

[c] Mean rankings obtained from the opinions of the respondents. Opinions were ranked from 1 (strongly disagree) to 5 (strongly agree).

[d] SD: Standard Deviation.

Question 12 aimed to determine whether managers and supervisors are approachable and if they are concerned with the suggestions and/or comments from the employees. A mean rating of 4.0 was obtained for this question, with a relatively high standard deviation of 0.943 (Table 4.2). The results indicate that employees agree that they can talk to their supervisors about topics related to work. However, 10% of employees indicated that they were unsure whether they could talk to their supervisors and 10% indicated that they could not talk to their supervisors freely. During the interviews, only a few employees (20%) stated that they could consult their supervisors if they felt unsure about work related issues. However, one employee mentioned that the supervisors are indeed unapproachable.

Question 13 focussed on the level of communication between employees and supervisors. A mean rating of 4.5 (SD=0.707) was obtained (Table 4.2), indicating that employees strongly agree that there is a good stream of communication between operators and supervisors. During the direct observation technique, it was seen that the managers discuss the product yield of the previous day as well as communicate the goals of the current day with the employees before the start of production. Management said the reason for this is to motivate the staff and to ensure that everyone is working towards the same goal.

The final two questions of the third section focussed on how serious the supervisors are about food safety and how the supervisors usually handle non-conformance issues. A mean rating of 4.6 (SD=0.699) was obtained for question 14 (Table 4.2), indicating that most employees strongly agree that their supervisors take food safety principles seriously. Furthermore, a mean rating of 4.7 (SD=483) was obtained from question 15 (Table 4.2). The high rating indicates that employees strongly agree that supervisors handle non-conformance in a constructive and respectful way. Corresponding results were obtained from the interviews with the production line employees. Sixty percent said that the supervisors are very serious, because there is a zero tolerance policy when it comes to non-conformance to food safety principles and that disciplinary hearings are instituted when necessary. The occurrence of disciplinary hearings was corroborated by the managers and supervisors.

Furthermore, it was established in the interviews with the managers that good manufacturing practices are important to them, as there is currently an employee evaluation system in place. The managers make use of a scorecard on which the employee's punctuality, behaviour, occupational health and safety skills, and housekeeping practices are evaluated at each production run. Every month, the person with the highest score receives a prize and every three months the overall winner is announced at a team-building event. The managers introduced the system to promote healthy competition among employees. Meetings are arranged with employees that achieve low scores during production runs in order to discuss their weak and strong points and to establish areas for improvement.

4.2.4.2 Discussion of Identified Risks and Control Strategies

It is deduced from the results that the managers of the catfish processing pilot plant take the implementation of food safety principles seriously through following up all incidents of non-conformance and by evaluating staff performance at each production run. This is a simple method of continuous improvement, as employees are able to learn from their mistakes after every production run, and it will benefit the company on the long run. Research conducted by Ball *et al*. (2009) established that employees regard positive performance feedback as a major motivation. It is therefore recommended that meetings also be held with employees that achieve relatively good scores during the month, and not only with employees that performed the worst.

However, risks concerning management commitment have been identified from the results. Supervisors fail to be a good example for the employees and fail to consider suggestions made by employees. Ball *et al*. (2009) established that it is important for employees to see that their superiors are implementing the same principles that they are required to implement. Once the employees become aware of the fact that their supervisors are also complying with the food safety principles, the food safety system is not regarded as pointless, unnecessary, and burdensome anymore. Furthermore, employees feel empowered when they are involved in food safety and technological changes within a facility (Holt & Henson, 2000), therefore it is important that their comments and suggestions are heard and considered by their superiors.

The failure of supervisors to lead by example and the failure of involving operational staff can be regarded as a lack of managerial commitment and leadership, which is a major limiting factor for the effective implementation of food safety systems (Panisello & Quantick, 2001). The lack of proper leadership will demotivate the food handlers and will eventually result in employees returning to their old habits, thus posing a risk to food quality and the financial health of the company. The probability of this risk occurring is likely, and the impact of this risk is major in terms of food safety, thus characterising the risk level as high (Table 3.1).

This risk can be mitigated by introducing formal employee suggestion programmes and by regularly evaluating the performance of managers and supervisors. A formal employee suggestion programme can be described as a system that encourages employees to think innovatively about their work and work environment by introducing incentives for any idea that will benefit the organisation (Marx, 1995). However, these programmes have to be supported by top management. Nevertheless, suggestion programmes offer a systematic way in which the comments and suggestions of employees can be heard and considered. Furthermore, the continuous evaluation of management/supervisory performance will encourage managers and supervisors to perform their duties in an appropriate manner.

4.2.5 Employee Morale

Data obtained from the final section of the questionnaire (questions 16 to 20), as well as the qualitative information obtained from interviews with the production line employees, were used to identify relevant risks that relate to employee morale in the company.

4.2.5.1 Results

The statistical analysis of the final section of the questionnaire is presented in table 4.3. The first question of this section (question 16) obtained a mean rating of 4.1 (Table 4.3), indicating that if the employees had the chance, they would choose the same profession again. However, 20% of the employees indicated that they were unsure whether they would choose the same profession again.

Question 17 aimed to determine whether employees feel challenged by their work on the catfish processing line. A mean rating of 3.6 was obtained making it the response with the lowest mean rating (Table 4.3). A relatively large standard deviation of 1.430 (Table 4.3) was obtained, indicating controversy on this topic. More specifically, 30% of employees indicated that they do not feel challenged by their work. In the interviews, the employees mentioned that it was difficult to implement the food safety principles at the beginning, but that HACCP becomes a part of one's life and becomes a second nature with time. Some employees also indicated that their previous experience in the food industry makes it less challenging to implement food safety practices.

Table 4.3 The standard deviation and mean ratings obtained for the section of the questionnaire, which focused on work satisfaction and the motivation of employees

Question no. [a]	N [b]	Mean [c]	SD [d]
16. If I had a chance to choose my profession again, I would choose the same thing.	10	4.1	0.789
17. I feel challenged by the work I do in the factory.	10	3.6	1.430
18. The current factory conditions enable me to carry out my duties with regard to food safety principles.	10	4.1	1.197
19. I feel motivated and supported by my co-workers.	10	4.6	0.516
20. My co-workers practise good hygiene principals.	10	4.6	0.516

[a] Complete questionnaire in Appendix B.

[b] Number of respondents.

[c] Mean rankings obtained from the opinions of the respondents. Opinions were ranked from 1 (strongly disagree) to 5 (strongly agree).

[d] SD: Standard Deviation.

The following question focused on determining whether the working conditions in the facility enable employees to implement food safety practices. A positive response, with a mean rating of 4.1 was obtained (Table 4.3). The standard deviation of the response was relatively high (1.197), indicating a variation in the responses. A minority (10%) of the employees indicated that they strongly disagreed that the working conditions enable them to carry out food safety practices effectively, while 40% strongly agreed. During the interviews, employees stated that working from the pilot plant at CPUT is very challenging as the production plan is never constant and the environment is unfamiliar. However, the employees mentioned that the working conditions would improve once the factory is operating from Graaff-Reinet.

Questions 19 and 20 focussed on the attitude of employees toward their co-workers. Question 19 aimed to determine the degree to which employees are motivated by one another, and question 20 focused on whether employees feel that their co-workers practice good hygiene principles. A mean rating of 4.6 was obtained for both these questions (Table 4.3), indicating that more than 50% of the employees strongly agree that they feel motivated by their co-workers and that their co-workers practise good hygiene principles. Corresponding results were obtained in the interviews. These results were discussed in *section 4.2.3.1*.

Furthermore, the production line employees were asked whether there are certain workstations on the production line that they prefer to operate. Forty percent of the respondents said that there was a specific position that they enjoyed, however, all of these respondents also mentioned that they think position rotation on the line is important in order to gain a variety of skills and in effect, be flexible on the production line. Fifty percent of the respondents said that they like to rotate because they experience different things and it makes their work more interesting and less repetitive. Nevertheless, 20% of the respondents said that they prefer to stay on one station because they want to acquire specialised skills. It was established that the managers rotate the employees after each production break so that they received training on all the different stations, in order for them to be able to stand in for one another if necessary.

4.2.5.2 Discussion of identified risks and control strategies

The relatively high mean ratings overall indicate that there is a positive morale among the employees working on the production line. The fact that employees agreed that they would choose the same profession again indicate that they have some degree of job satisfaction at their current work. It is also evident that the employees are positively challenged by the implementation of food safety principles, which may indicate that implementing HACCP in the future may be less burdensome to the employees. However, some of the employees did feel that their work is not challenging enough. Literature (Ramlall, 2004) suggests the lack of challenging work can affect the motivation of an employee. A dull and monotonous job or activity supresses motivation, while a challenging job stimulates motivation (Ramlall, 2004). Lack of motivation in food handlers pose as risk with regard to food safety compliance (Bertolini *et al*., 2007; Fotopoulos *et al*., 2009), and potentially, food quality.

There are various methods of making a task or a job more challenging, such as adding variety and inducing independent decision-making (Ramlall, 2004). Variety is added by allowing job rotation, which is already implemented in the pilot plant. The results indicated that most of the employees enjoy rotating between workstations. Job rotation promotes job satisfaction, however, there are risks involved, especially in the catfish processing plant. The more specialised tasks are conducted manually on the production line, such as the evisceration and the filleting tasks. These tasks require a certain level of skill in order for the product to leave the station with a standard quality. According to Malan (2016), employees working at the evisceration and filleting station should be highly skilled in these operations, as the difference between a skilled filleting employee and a moderately skilled employee can be 10% product yield. Less equipped employees will take longer to produce the same quality product. This was established during direct observation when a naturally skilled employee filleted a fish in 104 seconds and a less skilled employee took 243 seconds to complete the same task – more than twice as long. Evidently, the company is exposed to risk if job rotation is applied, but also if it is not applied. This decision should be made so that the result aligns with the goals and strategies of the company.

The response among employees with regard to their co-workers was generally positive. The results indicated that employees influence each other positively when it comes to implementing food safety practices. Research conducted by Jevšnik *et al*. (2008) indicated that employees who are satisfied with their interpersonal relationships at work tend to conduct better hygiene practices. Team-building activities can therefore enhance the implementation of food safety systems. The risk of having employees with poor interpersonal relationships with their co-workers is associated with low employee motivation, and thus poor job satisfaction, which ultimately leads to poor productivity.

4.3 Material-Flow analysis

The methodology and results obtained for the mass balance was validated by conducting an interview with an expert in the field of operations. It was recommended that more focus be placed on the variables losses during production runs, as the loss in raw material poses a major financial loss. The material flow model was adjusted accordingly and available data was used to make the required assumptions. As a result, the product flow in the CPUT-based pilot plant and the operations at Le Cap Foods, illustrated in Appendix A.1 and A.2, respectively, were quantified through conducting a mass-balance analysis and risks related to the actual production yield as well as product waste, were identified.

4.3.1 Results

A diagramme of the results obtained for the material mass balance of the production line at the CPUT-based pilot plant is presented in Appendix C. Table 4.4 presents the mean weight obtained for the fish prior to processing as well as the mean weight of the fish after the slime was removed. The difference of 0.031 kg is taken as the weight of the slime lost during the cleaning process, which is categorised as a wanted loss.

Table 4.4 Mean (kg) and standard deviation for the mass balance data obtained for the product prior to processing and after cleaning

Product	Mean (kg)	SD
Prior to processing	1.035	0.109
After pressured water spray	1.004	0.104
Difference	**0.031**	

The mean weight of the fish prior to processing (1.035 kg) was used to calculate the theoretical yield of components obtained at each step of the production process. Table 4.5 presents the mean weight obtained for each component of the whole fish that forms part of the main product. The standard deviation (SD) of each measurement is presented. The SD obtained for all measurements are relatively small, except for the weight obtained for the organs (fat, liver, eggs/testes). This is because the organs of both female and male fish were measured and the eggs of the female are much larger (mean=0.093 kg) than the testes of the male (mean=0.039 kg).

Table 4.5 Mean (kg), standard deviation and theoretical yield calculated from the material mass flow data for all components used in the main product (fish mince)

Component	Mean (kg)	SD	Theoretical Yield (w/w %)	Yield after mincing (w/w %)
Fat, liver, eggs/testes	0.059	0.038	6.03	
Side fins	0.012	0.002	1.19	19.94
Back-bone	0.155	0.038	15.02	
Skinned fillets	0.395	0.040	38.13	37.92
Total	**0.574**		**60.37**	

The theoretical yield presented in Table 4.5 of each component of the main product does not factor in the occurrence of variable losses in the production line. Therefore, a mass balance was conducted to determine the degree to which variable losses occur (Appendix C). Table 4.5 indicates that when the fillets are cut, the theoretical yield of the fillets decreases to 37.92% after the fillets are cut. The product loss observed during this process is classified as an unwanted loss, as 0.21% of the main product yield is lost. Similarly, when the components of the softs are put through the 6mm mincer, as well as the Comitrol, the theoretical yield decreases from 22.24% (when summed) to 19.94%. This loss is more significant to that of the fillets, most likely because the softs undergo more harsh mincing processes. This loss is also classified as an unwanted loss. The theoretical yields obtained from the mass balance were used for further calculations as it is a more accurate representation of the yield obtained on the current production line.

Furthermore, Figure 4.1 illustrates that a majority (70%) of the "meat block" consists of minced fillets, while the softs make out a small portion (30%). The "softs" consist of the fat, liver, eggs/testes, side fins, and back-bone, with a theoretical yield of 19.94% (Table 4.5). The fillets have a very high value, thus all of the minced fillets produced during a production run is used in the main product. The softs are then added to the minced fillets so that the ratio is 30:70 (softs:fillets). This, however, means that an excess of softs is produced during every production run. The following scenario will establish the excess amount of softs produced in a batch of whole fish.

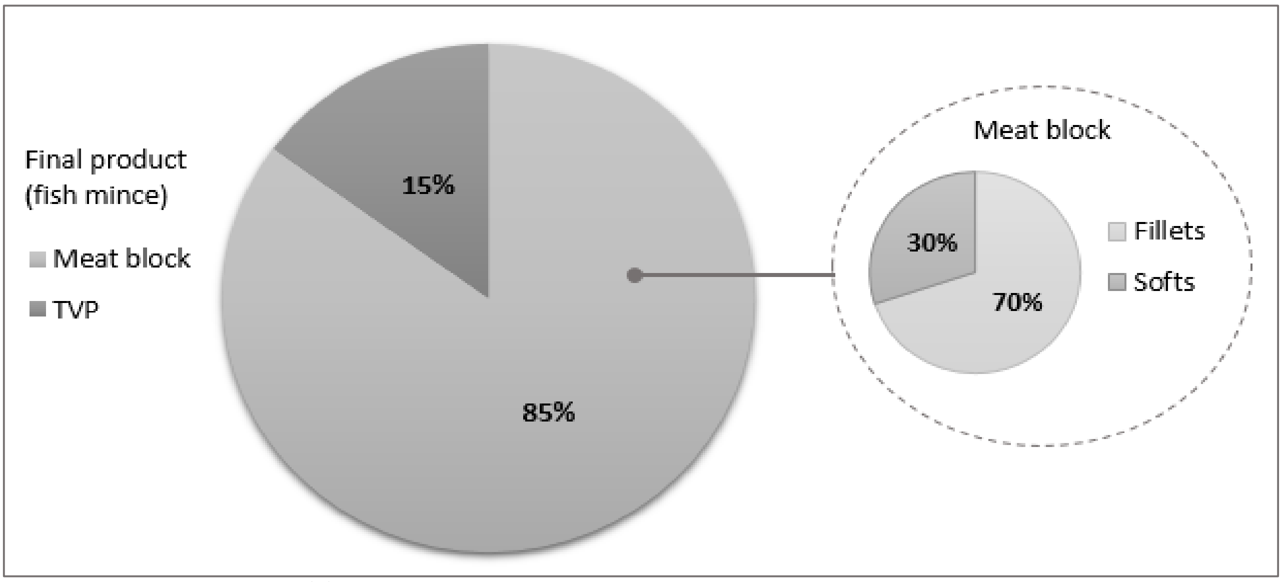

Figure 4.1 Composition of fish mince (15% HTVP).

In a 500 kg batch of raw whole fish, the following theoretical yields in mass (kg) are obtained for the minced fillets and the softs according to equation (2):

$$M_{Minced\ fillets} = \frac{37.92}{100} \times 500 \ = \ 189.60\ kg$$

$$M_{softs} = \frac{19.94}{100} \times 500 \ = 99.70\ kg$$

Where the 189.60 kg obtained for the minced fillets represent 70% of the meat block. The following calculation was employed to determine the amount of softs to be added to the meat block in order to obtain a 30:70 ratio:

$$M_{softs\ to\ be\ added} = \frac{189.60}{70} \times 30 = 81.26\ kg$$

Therefore, only 81.26 kg of the total 99.70 kg softs are used to produce the meat block, meaning that an excess of 18.50 % softs are produced every production run. Furthermore, according to equation (1), the theoretical yield for the meat block is calculated as:

$$PY_{Meat\ block} = \frac{189.60 + 81.26}{500} = 54.17\ \%$$

Figure 4.1 illustrates the addition of Hydrated Texturized Vegetable Protein (HTVP) to the meat block, which acts as a bulking agent for the fish mince. Equation (1) was further employed to calculate the theoretical yield of the product if 15% HTVP is added, and if 45% is added:

$$PY_{Fish\ mince;\ 15\%\ TVP} = \frac{189.60 + 81.26 + (\frac{189.60 + 81.26}{85} \times 15)}{500} = 63.73\ \%$$

And

$$PY_{Fish\ mince;\ 45\%\ TVP} = \frac{189.60 + 81.26 + (\frac{189.60 + 81.72}{55} \times 45)}{500} = 98.57\ \%$$

However, the above calculations do not consider variable losses that occur at the final mixing process. The mass balance (Appendix C) established that approximately 1.35% of the mixture is lost during the mixing process. Therefore, a more accurate representation of the theoretical yield is 62.38% if 15% TVP is added. The theoretical yield was compared with the average actual yield obtained during production runs (Fig. 4.2). The average actual yield obtained for the softs is approximately 17.26% (SD=0.017), making it 2.68% less than the theoretical yield obtained from the mass-balance calculations (Fig.4.2). This difference is small relative to the data obtained for the fillets. The average actual yield obtain for the fillets were approximately 27.84% (SD=0.103), making it 10% less (Fig.4.2) than the theoretical yield calculated. The average yield obtained for the meat block during production was 42.85% (SD=0.110). Thus, the actual yield was much lower (11.32%) than the theoretical yield calculated. Lastly, an average main product (15% HTVP) yield of 43.94% (SD=0.070) was obtained during production runs, making it approximately 18% less than the estimated theoretical yield (Fig. 4.2).

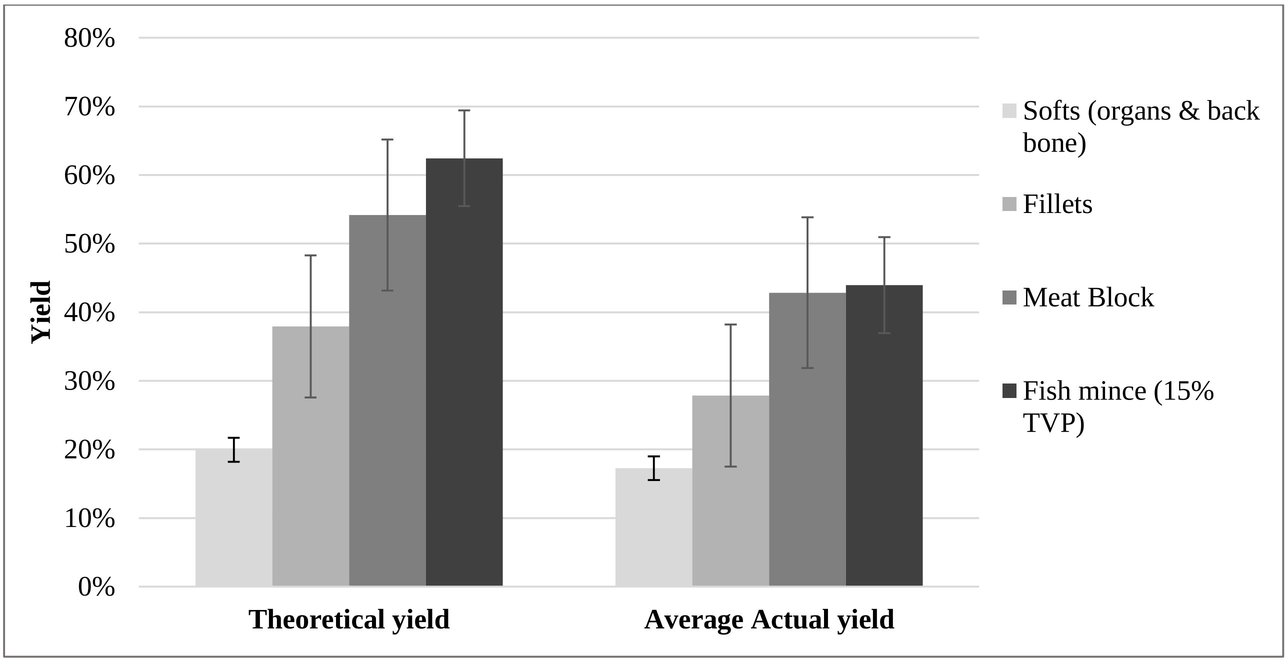

Figure 4.2 Comparison between the theoretical and actual yield of the main product (fish mince) and the constituents of the product.

Table 4.6 presents the mass-flow data obtained for the constituents of the by-product, which is produced and sold as pet food. The lungs and gills make out the majority (16.44%) of the pet food, while the tail fin contributes the least (1.06%) (Table 4.6). The tail fin was added to the pet food instead of the main product as the National Regulator for Compulsory Specifications (NRCS) mandates the removal of tail fins from fish products that are produced for human consumption (NRCS, 2004). The estimated theoretical yield of the pet food is 30.55% per batch of whole fish (Table 4.6). However, it should be mentioned that the blood of the fish obtained during production is also added to the pet food, but Table 4.6 does not include the data for the blood. The actual yield is thus expected to be a bit more.

Table 4.6 Mean (kg), standard deviation and theoretical yield calculated from the material mass flow data for all components used for the pet food product

Component	Mean (kg)	SD	Yield (w/w %)
Head	0.164	0.020	13.05
Lungs and Gills	0.170	0.020	16.44
Tail fin	0.011	0.003	1.06
Total Pet Food	**0.345**		**30.55**

The theoretical yield calculated for the pet food was compared to the average actual yield obtained during production. The actual yield of pet food obtained was 24.22%, making it approximately 6.33% lower than the estimated theoretical yield. The pet food also undergoes a mincing process at which product loss is highly likely. However, this variable loss was not investigated during the mass balance.

Table 4.7 presents the mass balance data obtained for the wanted losses on the production line. The skin of the fish is currently regarded as waste as it does not form part of a sellable product, however, research is being conducted to create a value-added product from the skin. A total yield of 5.99% (SD=0.007) is lost due to the skin being discarded (Table 4.7). In addition, the gut and gall will potentially be processed into fertilizer that will be used on the farm in the future, but is currently treated as waste. Finally, the slime lost was also taken into consideration (Table 4.1). All of these components of the fish are regarded as wanted losses, as it will decrease the value of the sellable products if it is not thoroughly removed during processing. The total theoretical yield of the production waste was approximated as 10.97% (Table 4.7). The theoretical yield was compared to the actual yield of waste obtained during production. The average actual yield obtained during production was 11.12% (SD=0.019), making it 0.15% more than the estimated theoretical yield of the production waste.

Table 4.7 Mean (kg), standard deviation and theoretical yield calculated from the material mass flow data for product waste

Component	Mean (kg)	SD	Yield (w/w %)
Slime	0.031	-	2.98
Gut and Gall	0.021	0.005	2.00
Skin	0.062	0.007	5.99
Total	**0.083**		**10.97**

Table 4.8 presents a summary of the undesired losses that were observed on the production line at CPUT during the mass balance (Appendix C). The weight presented in Table 4.8 is the weight of product, per batch of 500 kg fish, lost during processing at the specific production step. It was estimated that a total amount of 4.66% of a batch is undesirably lost during production (Table 4.8). However, this excludes the 18.50% of softs being wasted (3.69% of a batch).

Table 4.8 The weight and percentage yield of undesirable losses occurring during production at CPUT per 500 kg batch

Processing step	Weight (kg)	Yield (w/w %)
Filleting	2.447	0.49
Skinning	2.242	0.45
Bowl cutter	1.051	0.21
6mm Mincer	2.210	0.44
Comitrol	8.601	1.72
Mixer	6.756	1.35
Total	**23.307**	**4.66**

The composition of the packaged and cooked product produced at Le Cap Foods is presented in Table 4.9. According to the theoretical yield obtained for the 15% HTVP fish mince, on a 500 kg batch of whole fish, the CPUT-pilot plant is able to produce a maximum of 311.910 kg (62.38%). Table 4.9 presents that the cumulative, theoretical yield that is obtainable from a 100% efficient line of Le Cap Foods is 97.78%. This yield is of course calculated based on the 500 kg of whole fish received at CPUT. Alternatively, the theoretical yield calculated for the product produced by Le Cap in terms of the amount of product received by Le Cap, is 156.74%.

Table 4.9 Theoretical yield of final product at Le Cap for a full efficient line

Ingredient	Content (%)	Weight (kg)	Yield (w/w %)
Fish Mince	63.80	311.910	62.38
Thickener	0.20	0.979	0.20
Filler	1.00	4.893	0.98
Salt	0.20	0.979	0.20
Sauce	34.80	170.130	34.06
Total	**100**	**488.88**	**97.78**

The theoretical yield was compared with the actual yield obtained during a production run. During a production run where 200 g pouches with sauce were produced, 120 kg of the meat block was used. The production run delivered 871 pouches of approximately 200 g each, effectively amounting to 174.20 kg of final product. The resulting yield obtained by Le Cap was calculated as 145.17%. However, during this production run, a total of

12.42 kg of final product was wasted due to over-production. The 12.42 kg of waste is thus responsible for the 10% deviation between the actual yield and theoretical yield.

4.3.2 Discussion of Identified Risks and Control Strategies

The results obtained for the material mass balance indicated that the average yield obtained during production is less than the theoretical yield estimated for all the products and some components. There is a slight discrepancy between the actual yield of softs and the theoretical yield. This loss in yield could mean that the employees on the production line place some of the high-value organs into the waste bucket, which could also be the reason for the high waste (gut and gall) yield. The loss of high-value organs poses a financial risk, as it could have been added to the pet food or the main product to generate an income.

Furthermore, the low yield of the fillets could be a symptom of poor filleting. Fillets are high-value products and such a large discrepancy in yield (10%) could be costly to the company, especially when the fillets are sold individually. Poor filleting results in excess meat remaining on the back-bone, leading to the fillet meat ending up with the softs, and as mentioned in the results section, almost 20% of the softs are wasted. Too little yield of fillets obtained from a batch means that additional raw material will be used to compensate for the decreased yield. Henningsson *et al*. (2001) established that the food industry's biggest potential for cost saving lies in waste minimisation through improved raw material management. This was corroborated by the information obtained from the interview conducted with an expert in the field of operations management and food processing. Henningsson *et al*. (2001) further state that accurate auditing, improved raw material handling, and staff training are key factors for reducing raw material waste. The risk of raw material waste is also identified by the 4.66% undesirable waste occurring along the production line during processing. This will have long-term financial impact on the company if the risk is not effectively managed.

The fact that almost 20% softs are produced in excess is a significant waste for the company in terms of time and money and is therefore identified as a risk. The organs and back-bone are taken through the whole production process and are only discarded at the end of production. This means that direct labour and other manufacturing costs that are spent on the product is wasted. The excess softs can be added to the pet food, but the pet food is a lower value product and more profits are generated from the main product. In order to avoid profit loss, raw material wastage, and increased production costs, the meat block recipe can be altered in such a way that the proportion of softs added to the minced fillets is larger. For instance, changing the proportion from 30:70 to 34:66 (softs:fillets) will result in a theoretical meat block yield of 57.45%, which is 3.28% more than the current recipe. Furthermore, the 34:66 ratio will enable the production team to use almost 100% of the softs produced, thus resulting in minimal waste. However, there is a risk of altering the standard quality of the minced fish by adding more softs or by changing the recipe. Nevertheless, the company is primarily in the development phase, thus giving the company a chance to change the specifications of the product. It is therefore suggested that trials should be conducted before the change is implemented to determine what effect it has on the quality of the product and if the potential customers are satisfied.

The difference between the average actual yield obtained for the main product (15% HTVP) and the calculated theoretical yield is relatively large (18.50%). The main product has a high market value and a low production yield will have a significant impact on the revenue of the company and therefore poses a risk. The low yield at this stage can be attributed to poor production planning, and as a result, limited production time, as well as the lack of adequate staff training and motivation. The risk can be controlled by implementing a mass balance procedure and by conducting accurate record-keeping of production weights on the production line, especially at the mincing stations. The mass-balance will enable the managers to determine the amount of shrinkage that occurs during mincing and transportation. According to literature (Somsen & Capelle, 2002), unwanted losses occur regularly during in-house transport operations as a portion of the product remains in the machine or the product is spilled on the way to the next operation. Careful material handling, accurate record keeping or weight measurements will assist with the reduction of unwanted product loss but will require some form of training. Furthermore, the goals of production yield can be shared with the employees working on the production line in an attempt to motivate the employees to achieve the company goals. Instructing the employees on what is expected of them has proven to be effective in improving product yield (Somsen *et al*., 2004). The same principles can be applied to improve the actual yield of the pet food obtained. Although this product has a much lower sellable value, it is still regarded as a financial risk, as the company will obtain a lower revenue and profit margins may be affected.

4.4 Line Balancing

The line balancing (LB) model was created once results were obtained from the time study and the material mass flow. The following section will present the theoretical results obtained from applying LB principles to the developed model of the production line at both the CPUT-based pilot plant and Le Cap Foods. The methodology used as well as the results obtained for this section was validated by presenting the information to an expert in the field of operations management. Upon validation, productivity and efficiency risks were identified in the catfish processing line with the means of the LB model and control strategies were finally proposed.

4.4.1 Line Balancing at the CPUT-based Pilot Plant

Through observing the production line at the CPUT-based pilot plant, it was established that the production process consisted of three lines, of which two were involved in the production of the main product. These two lines were identified as line 1 and line 3. Line 2 involved the preliminary processing of the pet food. However, pet food did not form part of this study; therefore, LB was not applied in line 2. The standard time (ST) ratings obtained for each workstation in lines 1 and 3 were obtained from the time study. The allowance factors allocated to line 1 at the CPUT-based pilot plant is presented in Appendix D.1, and the allowance factors allocated to line 3 is presented in Appendix D.2. The following sections will discuss the current operations in the production line, after which two LB methods are proposed.

4.4.1.1 Current operations

Table 4.10 presents the workstations identified for line 1 of the CPUT-based pilot plant, as well as the jobs associated with each workstation. The in-house transport activities were identified as workstations due to transport activities being crucial for production flow in the facility. Furthermore, in some instances more than one production process was allocated to a specific workstation, as it was identified during observation that certain consecutive processes were conducted by the same employee without moving from a particular position. For instance, the same employees who trim the fish, fillet the fish as well. This also applies to the packaging and mixing processes.

Table 4.10 Normal and standard time ratings for the workstations in line 1 as well as the number of employees and cycle time per employee at each workstation for the current operation

Workstation no.	Job description	Average normal time [min.kg^{-1}]	Standard time [min.kg^{-1}]	No. of employees	Cycle time per employee [min.kg^{-1}]
1	Transport A	0.01	0.02	2	0.01
2	Pre-cooker rinser	0.07	0.07	1	0.07
3	Hot water dip	0.28	0.32	1	0.32
4	Water spray	0.13	0.14	1	0.14
5	Evisceration	1.84	2.06	3	0.69
6.1	Cut Fins & Fillet	3.31	3.76	4	0.94
7.1	Skinning	0.28	0.31	1	0.31
7.2	Bowl cutter	0.21	0.43	1	0.43
7.3	Transport D	0.05	0.06	2	0.03
8	Transport E	0.03	0.03	2	0.02
9	Mixing & packaging	0.06	0.07	2	0.04
10	Transport F	0.03	0.04	2	0.02
		Total		**22**	**3.01**

The number of employees at each workstation presented in Table 4.10 was identified through observation. Table 4.10 indicates that the current operation requires 22 employees to run production line 1. However, it was established that there were only 20 people working in the production facility, two of whom were supervisors who regularly assisted on the production line. Thus, employees were shifted between workstations within the production line, depending on where they were needed. The fact that employees were not allocated to one specific station was also established in the interviews. Therefore, the number of employees at each station presented in Table 4.10 were the number of employees working at that specific station during the observation process. It was also established that employees on line 1 assist with operations on line 3.

The time study results for line 1 is presented in Table 4.10. When a confidence interval of 90 was applied in equation (4), the required number of observations ranged from 50 to 60 cycles per element. Due to time constraints, the number of cycles to be observed as suggested by the equation was unachievable. However, a minimum of 15 cycles were observed per element. This is applicable to both lines 1 and 3. The aim of the study was to provide a systematic approach towards identifying operational risks, and therefore the statistical significance of the time study had little impact. Furthermore, the performance of employees was rated according to a standard that was established when the production line was observed. The average time allowance allocated to each workstation amounted to 12%, where the evisceration workstation was allocated the most (15%) and the water spray, skinning, and bowl cutter workstations were allocated the least (10%). The performance ratings and the time allowances were considered in order to obtain the ST ratings presented in Table 4.10.

The bottleneck of the current operation was identified as workstation 6.1, as it had the highest cycle time per employee (0.94 min.kg-1) (grey shaded row in Table 4.10). Furthermore, according to equation (9), the takt time of a production line is calculated by obtaining an average customer demand; however, since the production operation of BKT is still at pilot plant scale, an average customer demand has not yet been established. Therefore, the takt time of the operation was calculated by considering the time constraints of the facility. The required processing rate was determined by observing the amount of whole fish processed per day and by investigating the net working hours of the employees per day. The employees of BKT worked from 8:00 to 16:30, with a 30-minute tea break and an hour lunch, amounting to seven actual working hours per day. Two working days in a month, thus 14 working hours, was made available to process 1000 kg of whole catfish at CPUT. In effect, the employees were required to process 500 kg of fish in seven working hours. The takt time (T) and the adjusted takt time (TA) of the current operation, with a standard 5% machine breakdown allowance, was calculated by employing equation (9) and (10), respectively:

$$T = \frac{7 \times 60}{500} = 0.84\, min.kg^{-1}$$

$$T_A = 0.84 \times (1 - 0.05) = 0.80\, min.kg^{-1}$$

The takt time of the whole production process is 0.80 min.kg^{-1}, meaning that the one kilogram of the product should be processed every 0.80 minutes (48 seconds) in order for the company to meet the production requirements. The production requirements can be met if every workstation down the production line performs its tasks within 0.80 minutes per kilogram. It should be noted that line 1 and line 3 have the same demand and production time, and thus the same takt time.

The cycle time of the bottleneck workstation (0.94 min.kg^{-1}) was more than that of the takt time, indicating that there is a lack of continuous and consistent flow in the production line. Figure 4.3 illustrates the degree to which the line is unbalanced. Research showed that an unbalanced line can lead to a lesser quality product, underutilized workforce, high inventory costs and poor worker morale (Simons & Zokaei, 2005). The current operations in line 1, therefore, pose a financial risk in terms of product quality and production costs.

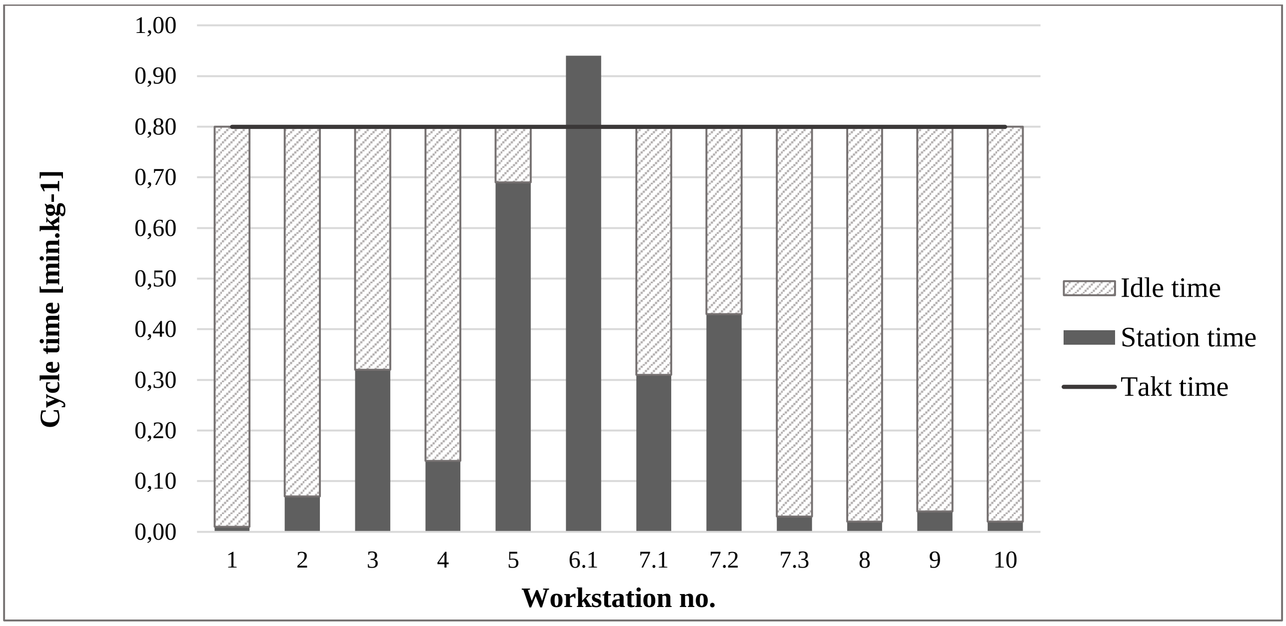

Figure 4.3 An illustration of the degree of idle time in production line 1 due to the discrepancy between the calculated cycle times of workstations (elements) and the takt time of the production line.

To analyse the operations further, the line efficiency was calculated by employing equation (8). The following efficiency (*E*) was obtained for the current operations in line 1:

$$E = \frac{100 \times 3.01}{12 \ \times 0.94} = 26.67\ \%$$

Where 3.01 min.kg^{-1} is the total cycle time in line 1 and 12 is the number of workstations (Table 4.10). A line efficiency of 26.67% suggests the presence of long waiting times and low labour utilisation. Control strategies for managing the identified risks will, therefore, involve the reduction of employees and workstations.

Similar to line 1, calculations were performed for line 3 in the CPUT-based pilot plant. The workstations identified for line 3 are presented in Table 4.11, as well as the time study results for each station. The bottleneck workstation for line 3 was identified as workstation 6.4, as it had the largest cycle time per employee (0.23 min.kg^{-1}) (Table 4.11). According to Table 4.11, seven employees are required to operate line 3 in its current state. However, employees from other workstations in line 1 assist with the operations in line 3 when possible.

Table 4.11 Normal and standard time ratings for the workstations in line 3 as well as the number of employees and cycle time per employee at each workstation for the current operation

Workstation no.	Job description	Average normal time [min.kg^{-1}]	Standard time [min.kg^{-1}]	No. of employees	Cycle time per employee [min.kg^{-1}]
6.2	6mm Mincer	0.09	0.10	1	0.10
6.3	Transport B	0.05	0.06	2	0.03
6.4	Comitrol	0.41	0.47	2	0.23
6.5	Transport C	0.02	0.02	2	0.01
		Total		**7**	**0.37**

The analysis of line 3 indicates that the cycle time of the bottleneck is lower than the takt time of the production line, meaning that there is excess capacity in the line. Figure 4.4 illustrates the large degree of idle time at each station in the current production operations of line 3. Therefore, similar to line 1, employees on line 3 are underutilised due to an unbalanced line. The line efficiency (*E*) of the current operations in line 3 was calculated by employing equation (8):

$$E = \frac{100 \times 0.37}{4 \times 0.23} = 39.81\%$$

Where 4 is the number of workstations identified in line 3 and 0.37 min.kg^{-1} is the total cycle time per employee (Table 4.11). The efficiency of line 3 is more than that of line 1; however, line 3 is much shorter and less time consuming than line 1.

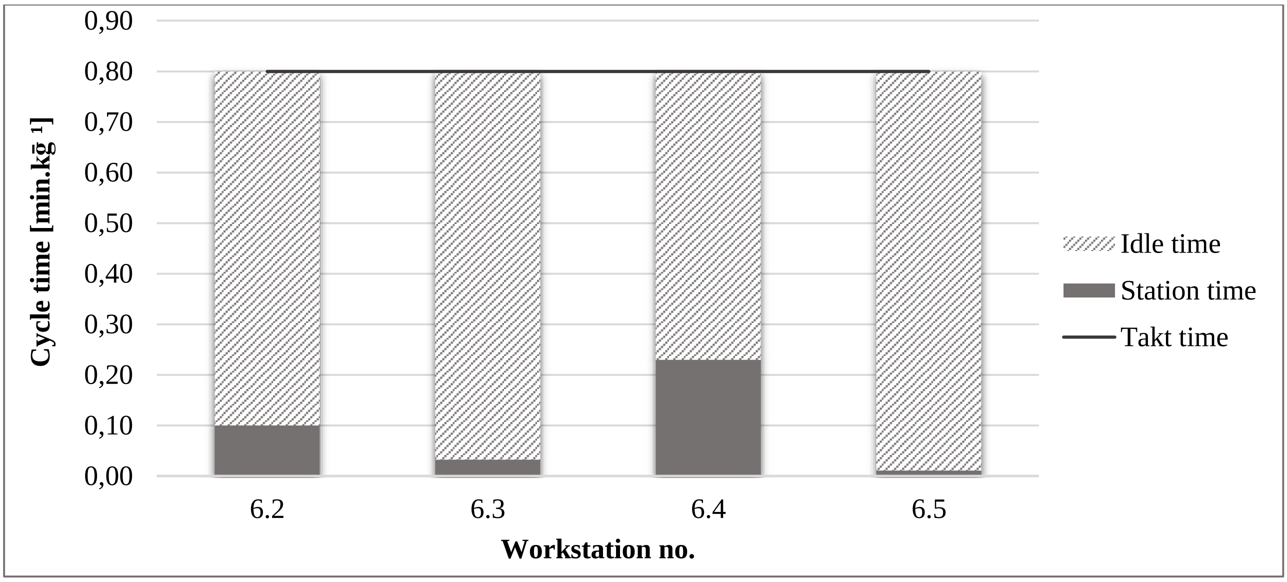

Figure 4.4 The degree of idle time in line 3 with a production line takt time of 0.80 min.kg^{-1}.

A network model of the current operations in line 1 and line 3 at the CPUT based pilot plant was created (Fig. 4.5). Figure 4.5 illustrates that line 3 splits from line 1 after workstation 6.1, the filleting workstation, and reconnects with line 1 at a transport workstation where components from both lines are transported from the cold store to the mixer in the butchery. Workstations 6.2 to 6.5 in line 3 run parallel to workstations 7.1, 7.2, and 7.3 in line 1, indicating that their production times should be similar to avoid onset delay of workstation 8. The sum of the workstation cycle times in line 1 is 0.77 $min.kg^{-1}$, and in line 3 is 0.37 $min.kg^{-1}$. The processing operations in line 3 are therefore twice as fast as the operations in line 1, thus indicating zero waiting time for line 1.

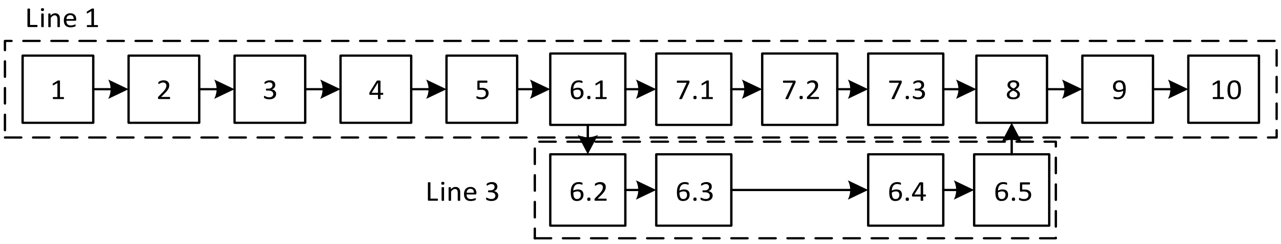

Figure 4.5 A network model of the current operations in the CPUT based pilot plant.

The analysis of the current production operations at the CPUT-based pilot plant led to the identification of risks related to the efficiency of the production lines. Poor efficiency may lead to low-quality products and long production runs, which in turn will result in high production costs and in effect, financial loss. The following sections discuss control strategies in the form of different line balancing methods.

4.4.1.2 Method 1: Reduce and Reallocate Workforce

The first scenario focused on decreasing and reallocating the workforce in order to decrease the excess capacity in production line 1. The number of employees allocated to each of the transport workstations was reduced from two to one. The transport activities can be performed by one person with the assistance of a trolley to carry the load. Furthermore, resources were added to the bottleneck in order to reduce the cycle time of the workstation. Thus, the number of employees at workstation 6.1 (fin trimming and filleting workstation) was increased from four to five, resulting in a cycle time of 0.75 $min.kg^{-1}$ for this station (Table 4.12). Workstation 6.1 remains the bottleneck of line 1, but the cycle time of this workstation is now closer to the takt time of the production line. The number of employees allocated to workstation 9 (mixing and packaging workstation) was reduced from two to one, as it is possible for one person to perform the mixing and packaging jobs.

The efficiency of the operations in line 1, resulting from the first method, was calculated as 32.45%, almost 6% more than the current operations, thus indicating that the implementation of method 1 results in a more balanced production line. However, it should be noted that a complete time study should be conducted on the changed workstations to establish new time standards and to obtain more accurate information. The data in Table 4.11 are the adjusted time study results from the current production operations and are thus presented as a guideline. Furthermore, the total number of employees was reduced by four by implementing method 1. As previously mentioned, 20 employees are available to work on the production line. The extra two employees can, therefore, solely be allocated to line 3.

Table 4.12 The number of employees and cycle times for workstations in line 1 as a result of the first LB approach

Workstation no.	Job description	No. of employees	Cycle time per employee [min.kg^{-1}]
1	Transport A	1	0.02
2	Pre-cooker rinser	1	0.07
3	Hot water dip	1	0.32
4	Water spray	1	0.14
5	Evisceration	3	0.69
6.1	Cut Fins & Fillet	5	0.75
7.1	Skinning	1	0.31
7.2	Bowl cutter	1	0.43
7.3	Transport D	1	0.06
8	Transport E	1	0.03
9	Mixing & Packaging	1	0.07
10	Transport F	1	0.04
	Total	**18**	**2.93**

Similar to line 1, the number of employees working at in-house transport stations in line 3 were reduced from two to one. This change resulted in a 0.04 min.kg^{-1} increase in the total cycle time per employee of line 3; however, the bottleneck cycle time remained unchanged (Table 4.13). The line efficiency increased to 43.94%.

Table 4.13 The number of employees and cycle times for workstations in line 3 as a result of the first LB approach

Workstation no.	Job description	No. of employees	Cycle time per employee [min.kg^{-1}]
6.2	6mm Mincer	1	0.10
6.3	Transport B	1	0.06
6.4	Comitrol	2	0.23
6.5	Transport C	1	0.02
	Total	**5**	**0.41**

Furthermore, the results in Tables 4.12 and 4.13 indicate that line 3 will not cause a delay in production, as the total cycle time of line 3 (0.41 min.kg^{-1}) is less than the sum of the cycle times of workstations 7.1, 7.2 and 7.3 in line 1 (0.80 min.kg^{-1}). Thus, the component produced by line 3 (softs) will be available when mixing of the final product commences.

4.4.1.3 Method 2: Combining Jobs

In method 2, more than one job was assigned to employees in an attempt to reduce the number of workstations. Firstly, all the transport jobs were allocated to one employee. It is not necessary for the transport activities to be conducted simultaneously, thus making it feasible for one person to operate all of the transport jobs. This immediately reduced the required number of employees and workstations by three each. The workstation that involves the pre-cooker rinser (workstation 2) was not combined with other workstations, as the employee operating this workstation, has a large responsibility towards maintaining the flow of incoming product in the production line. The hot water dip and water spray jobs were combined into one workstation. This, however, is only feasible if the structure of the bath allows the fish to be submerged in the hot water for at least 7 seconds without the physical assistance of an operator.

Furthermore, the evisceration and filleting jobs were not combined into one workstation, as these jobs have the highest cycle times. Finally, the skinning and bowl cutter jobs were combined into one workstation in order to increase labour utilisation. Table 4.14 presents the results obtained for method 2 in production line 1. As in method 1, the presented data are based on the original time study results. In order to obtain a more accurate estimation of the standard times of the changed workstations, a complete time study should be conducted again. Thus, the results presented in Table 4.14 are considered a guideline.

The total cycle time per employee for production line 1 was reduced to 2.17 min.kg^{-1}(Table 4.14), making it 0.83 min.kg^{-1} faster than the current operations. The bottleneck of the line 1 as a result of method 2 was identified as workstation 5.1 (grey shaded row in Table 4.14); however, there is very little difference (0.03 min.kg^{-1}) between the cycle times of the workstation 4 and 5.1 (Table 4.14), thus indicating that the workload is balanced to a certain degree. Furthermore, the total number of employees required for line 1 was reduced by four, meaning that there are employees available to assist on line 3.

Table 4.14 The number of employees and cycle times for workstations in line 1 as a result of the second LB approach

Workstation no.	Job description	No. of employees	Cycle time per employee [min.kg^{-1}]
1a,b,c,d	Transport A, D, E,F	1	0.15
2	Pre-cooker rinser	1	0.07
3	Hot water dip & water spray	1	0.46
4	Evisceration	4	0.52
5.1	Cut Fins & Fillet	7	0.54
6	Skinning & Bowl cutter	2	0.37
7	Mixer & Packaging	1	0.07
	Total	**17**	**2.17**

The line efficiency resulting from applying the second method was calculated as 57.80%, making it the highest calculated efficiency thus far. The increased efficiency indicates that the production line, as per method 2, is more balanced. However, the cycle time of workstations 2 and 7 are both 0.07 min.kg^{-1} (Table 4.14), making it far less than the takt time and the bottleneck cycle time of the production line. Evidently, the employees working on these workstations are underutilised. The degree of idle time in production line 1 resulting from method 2 is presented in Figure 4.6. The underutilised employees can be allocated to cleaning activities or perhaps administrative jobs related to HACCP documentation on the production line. Alternatively, the two supervisors on the production line can assist with the jobs in workstations 2 and 7 in order for them to have time to perform their other responsibilities.

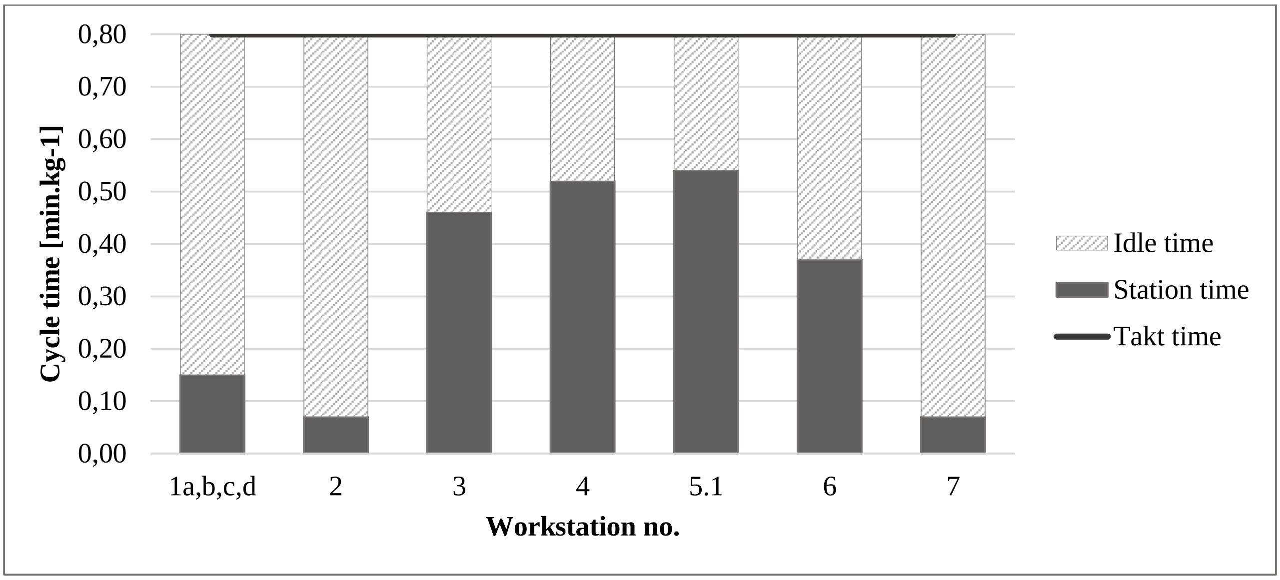

Figure 4.6 An illustration of the idle time for each workstation in line 1 after the second LB method was applied.

In addition, the jobs on production line 3 were also combined in the second LB method. One employee was allocated to operate the 6mm mincer and to transport the minced product to the next station (workstation 5.2, Table 4.15). Another two employees were allocated to operate the Comitrol and to transport the product from the Comitrol to the cold store (workstation 5.3, Table 4.15). These changes resulted in a total cycle time increase in production line 3, from 0.37 min.kg^{-1} to 0.40 min.kg^{-1} (Table 4.15). Nevertheless, the total cycle time per employee is less than the takt time of the production line, indicating that the capacity of the production line is not exceeded. Workstation 5.3 was identified as the bottleneck with a 0.24 min.kg^{-1} cycle time (Table 4.15). Method 2 reduced the number of employees by four and decreased the number of workstations by two. These changes resulted in a production line efficiency of 82.41%, indicating that the line is more balanced.

Table 4.15 The number of employees and cycle times for workstations in line 3 resulting from the second LB method

Workstation no.	Job description	No. of employees	Cycle time per employee [min.kg^{-1}]
5.2	6mm Mincer & Transport B	1	0.16
5.3	Comitrol & Transport C	2	0.24
	Total	**3**	**0.40**

Figure 4.7 presents the resulting network model resulting from method 2 for both lines 1 and 3. In order to avoid production delays in the improved production line, workstation 6 should have a similar cycle time as the sum of the cycle times of workstations 5.2 and 5.3 in line 3. Table 4.14 indicates that workstation 6 has a cycle time of 0.37 min.kg^{-1} and table 4.15 indicates that the total cycle time of line 3 is 0.40 min.kg^{-1}. The two cycle times are therefore very similar, indicating that a production delay is unlikely.

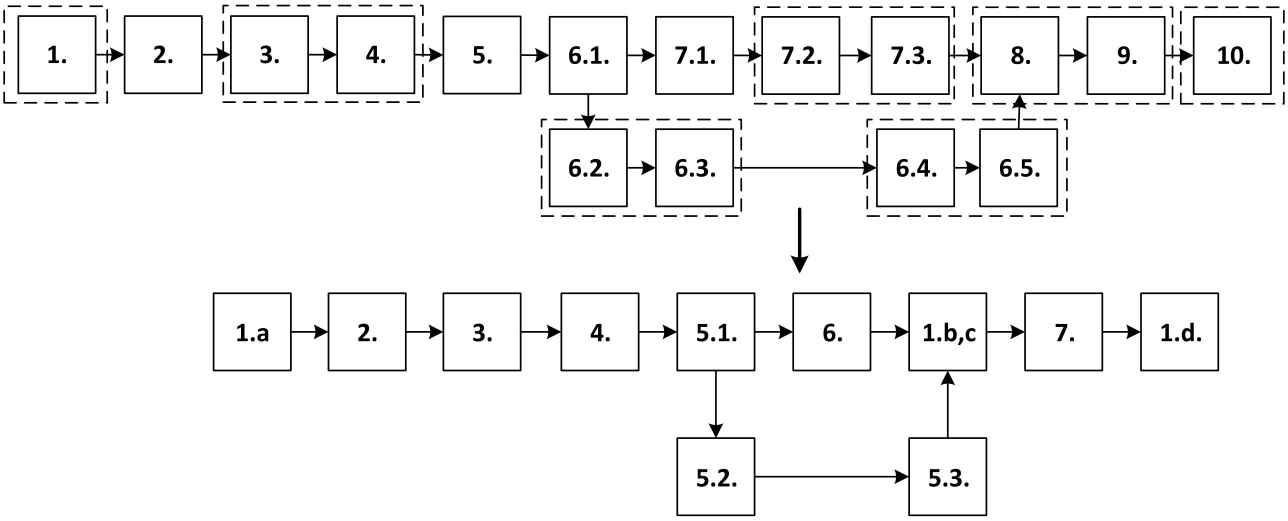

Figure 4.7 Network model of workstations in both lines 1 and 3 resulting from the second LB method.

4.4.1.4 Comparing Current Operations and Proposed Methods

The current and proposed production operations (methods 1 and 2) have benefits as well as risks related to the implementation of each. The first method is straightforward to implement, as the number of employees per workstation was simply reduced. However, in order for the method to be viable, a trolley should be made available at all points were transport activities take place. Furthermore, the workstations were not decreased by method 1, but the bottleneck time was decreased, thus ultimately resulting in the line efficiency increasing from the current operation (Table 4.16).

The second method would be more difficult to implement than the first method, as jobs are combined and workstations are reduced. Combining jobs in the production line evidently led to higher labour utilisation, which in turn is related to financial and operational benefits. However, the employees on the production line may perceive the change differently. The potential for workforce resistance should be considered, as some of the employees will be working alone at their station due to the changes or the employees might feel that they are putting in more effort without a wage increase. In order to combat the resistance, the employees should be educated on the long-term benefits of balancing the workload and operating a more efficient production line. In addition, employees should be included in the change process by taking their views and suggestions into consideration.

Table 4.16 presents that the highest line efficiency was obtained through Method 2, for both lines 1 and 3. It is also seen that method 2 resulted in the shortest cycle time for the bottleneck in line 1. Method 2 succeeds in employing the exact amount of workers currently available on the production line. Nevertheless, management should waiver all benefits and risks associated with each LB approach, and should finally make a decision by considering the strategic business objectives and goals of the company.

Table 4.16 Comparison of current production operation and the other methods

Performance indicator	**Current operations**		**Method 1**		**Method 2**	
Line	**1**	**3**	**1**	**3**	**1**	**3**
No. of operators	22	7	18	5	17	3
No. of stations	12	4	12	4	7	2
Bottleneck cycle time [$min.kg^{-1}$]	0.94	0.23	0.75	0.23	0.54	0.24
Total cycle time per employee [$min.kg^{-1}$]	3.01	0.37	2.93	0.41	2.17	0.40
Line efficiency (%)	26.67	39.81	32.45	43.94	57.80	82.41

4.4.2 Line Balancing at Le Cap Foods

The process flow of the production line at the Le Cap Foods facility was described in section 4.1.2. During the discussion, it was mentioned that either the production line is manually operated or it is automatically operated, depending on the size of the pouch. The results discussed in the following section were obtained during a manually operated production run that involved the mixing and packaging of fish mince mixed with sauce in 200 g pouches. The standard time (ST) ratings for each workstation in the production line at Le Cap Foods were obtained from the time study and the allowance factors allocated to each workstation is presented in Appendix D.3. The results of the current production operations will be discussed as well as the identified risks, after which two LB methods will be proposed as control measures.

4.4.2.1 Current Operations

Table 4.17 presents the workstations that were identified in the production line at the Le Cap Foods facility. The numbering of the workstations was made continuous with the workstations at the CPUT-based pilot plant. The results of the average normal time, as well as standard time ratings for all workstations in the Le Cap production line, are presented in Table 4.17. In addition, the number of employees at each workstation was identified during observation, which ultimately allowed the calculation of the cycle time per employee for each workstation (Table 4.17). The bottleneck of the packaging line was identified as workstation 15 (grey shaded row in Table 4.17), as it had the highest cycle time per employee (1.54 $min.kg^{-1}$). It should be noted that these results are only applicable to the 200 g, manually packaged pouches. A complete time study should be conducted to obtain specific data for pouches of other sizes, as well as for the automated packaging line.

Table 4.17 Normal and standard time ratings for workstations in the Le Cap production line, as well as the number of employees and cycle time per employee at each workstation for the current operation

Workstation no.	Job description	Average Normal time [min.kg^{-1}]	Standard Time [min.kg^{-1}]	No. of employees	Cycle time per employee [kg.min^{-1}]
11	Transport G: storage to mixing	0.08	0.10	1	0.10
12	Weighing of materials, mixing, put in buckets	0.20	0.23	2	0.11
13	Transport H: mixing to filling	0.01	0.01	1	0.01
14	Open pouch	0.93	1.03	2	0.52
15	Weigh fish in pouch	2.78	3.09	2	1.54
16	Weigh sauce in pouch	1.91	2.13	2	1.06
17	Clean pouch and transport to sealing station	1.31	1.48	2	0.74
18	Vacuum seal	0.81	0.91	1	0.91
19	Heat seal	1.01	1.14	1	1.14
20	Mark and place on retort trolley	0.47	0.52	1	0.52
21	Transport I: to retort	0.03	0.03	1	0.03
22	Fill retort	0.05	0.05	1	0.05
23	Take out of retort	0.04	0.05	1	0.05
		Total		**18**	**6.78**

The takt time of the processing line was calculated by considering the production constraints of the facility. The production facility and the workforce of Le Cap were available for one day (seven working hours) in a month to package the fish mince received from CPUT. In the previous section, it was mentioned that the pilot plant at CPUT processed 1000 kg of the whole catfish in a month, and from the material-flow analysis section, the theoretical final product yield (15% HTVP) on 1000 kg is 624.40 kg (62.44%), which is thus the maximum amount of product that could be received by Le Cap Foods. The takt time (T) and the adjusted takt time (TA) of the current operation at Le Cap, with a standard 5% machine breakdown allowance, was calculated by employing equation (9) and (10), respectively:

$$T = \frac{7 \times 60}{624.40} = 0.67\ min.kg^{-1}$$

$$T_A = 0.66\ \times\ (1 - 0.05) = 0.64\ min.kg^{-1}$$

Thus, a kilogram of product should be processed every 0.64 minutes in order for the facility to meet the required production rate. It is seen that the cycle time of the bottleneck (1.54 min.kg^{-1}) is higher than that of the takt time, meaning that there is a lack of capacity in the production line. The current operations in the production line will therefore not be able to meet the required production rate and may resort to overtime. Furthermore, Figure 4.8 illustrates the unbalanced nature of the production line. Almost 40% of the workstations require more than 0.64 minutes to process 1 kilogram of product, while a majority of the remaining workstations use 0.10 minutes or less to process 1 kilogram (Fig. 4.8).

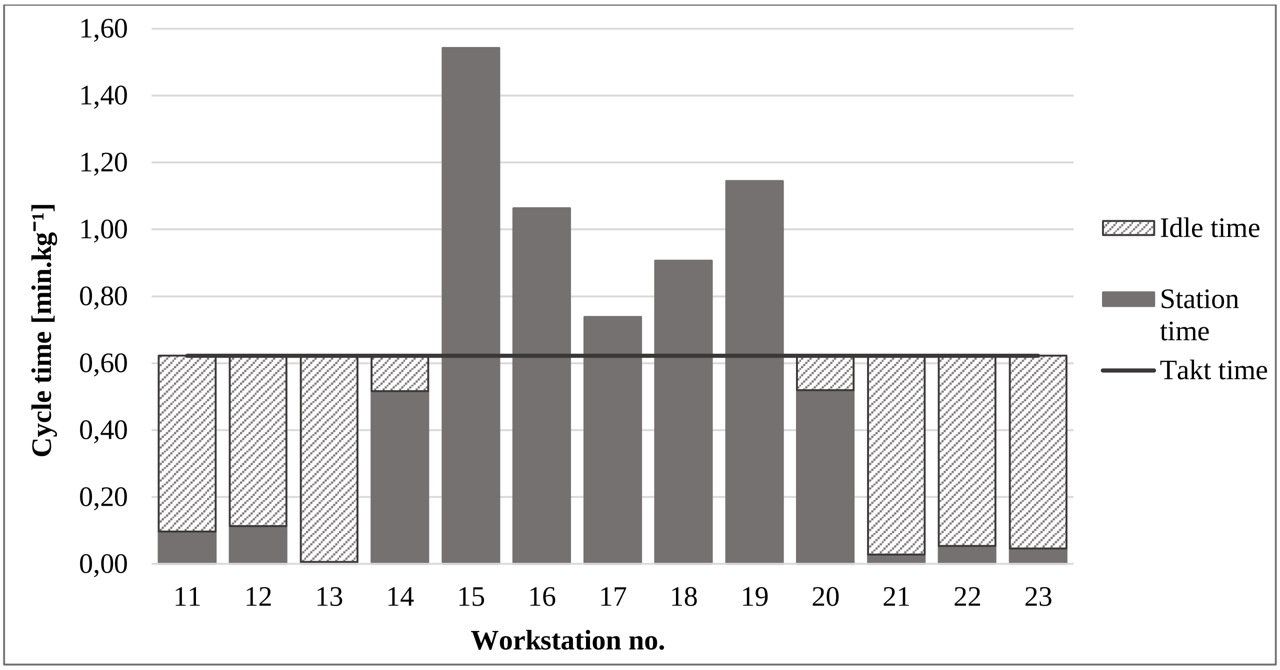

Figure 4.8 Workstation cycle times of the current production operation relative to the takt time of the production line (0.64 min.kg^{-1}).

The need for improvement in the current operations was further realised by analysing the theoretical line efficiency. The total cycle time per employee (6.78 min.kg^{-1}), the bottleneck cycle time (1.54 min.kg^{-1}), as well as the number of workstations (13) were obtained from Table 4.17. The line efficiency (*E*) was calculated by employing equation (8) as follows:

$$E = \frac{100 \times 6.78}{13 \times 1.54} = 33.82\%$$

A line efficiency of 33.82% further established that the current production operations would not be able to meet the required production rate. Failure to meet the required production rate will result in overtime. Overtime will increase the production costs significantly and may result in poor employee morale. Resources are poorly managed if the production line requires overtime, while some employees are underutilised as a result of an unbalanced production line (Fig. 4.8). In addition, employees that are being over-worked, and those that operate workstations that have a cycle time that exceeds the takt time, will most likely cut corners during processing to maintain the required production rate. This may lead to a poorer quality product and may adversely influence the profit margin of the company. The inefficiency of the production line, therefore, poses a risk with regard to the financial performance of the company, the quality of the product and ultimately, the production time of the facility. The following sections will discuss two line balancing approaches as strategies to control the identified risks.

4.4.2.2 Method 1: Increasing Capacity and Reallocating Workforce

The aim of the first method was to increase the capacity of workstations that had cycle times exceeding the takt time of the production line. The capacity was increased by allocating more resources to these workstations. However, the constraints of the company were considered while balancing the line. BKT currently employs 20 people on the production line; therefore, the maximum number of employees able to work on the packaging line was 20. In addition, only one vacuum and heat seal were available, therefore a maximum of one employee was allocated to each of these workstations. The result of applying method 1 is presented in Table 4.18. The cycle time per employee was calculated by dividing the original standard time of each workstation (Table 4.17) by the adjusted number of employees displayed in Table 4.18. In order to obtain more accurate results with regards to new time standards, a complete time study should be conducted on the adjusted workstations. The results in Table 4.18 are presented as a guideline.

Table 4.18 indicates that the changes have caused the bottleneck to shift from workstation 15 to workstation 19, the heat seal station, and has decreased the bottleneck cycle time by 0.40 $min.kg^{-1}$. However, almost 40% of the workstations still have cycle times that exceed the takt time. The results obtained for method 1 is, therefore, similar to the current production operations. Furthermore, the line efficiency resulting from the changes in the production line was 38.78%, which is only a slight increase (4.96%) from the current production operations. It was established that the capacity and the overall efficiency of the production line was restricted by the amount of employees available in the production facility, as well as the type and amount of sealing equipment available. Nevertheless, the operations resulting from method 1 is an improvement from the current production operations

Table 4.18 The number of employees and cycle times for workstations in the Le Cap facility as a result of the first LB method

Workstation no.	Job description	No. of employees	Cycle time/ employee [kg.min⁻¹]
11	Transport G: storage to mixing	1	0.10
12	Weighing of materials, mixing, put in buckets	1	0.23
13	Transport H: mixing to filling	1	0.01
14	Open pouch	2	0.52
15	Weigh fish in pouch	4	0.77
16	Weigh sauce in pouch	4	0.53
17	Clean pouch and transport to sealing station	2	0.74
18	Vacuum seal	1	0.91
19	Heat seal	1	1.14
20	Mark and place on retort trolley	1	0.52
21	Transport I: to retort	1	0.03
22	Fill retort	1	0.05
23	Take out of retort	1	0.05
	Total	**21**	**5.59**

4.4.2.3 Method 2: Combining Jobs

The aim of the second method was to increase labour utilisation by combing jobs into single workstations and to increase the line efficiency by essentially decreasing the number of workstations. Table 4.19 presents the results obtained by applying the second line balancing approach in the Le Cap production line.

Table 4.19 The number of employees and cycle times for workstations in the Le Cap facility as a result of the second LB method

Workstation no.	Job description	No. of employees	Cycle time per employee [kg.min⁻¹]
11	Transport G, Weighing, mixing, transport H	1	0.33
12	Open pouch	2	0.52
13	Weigh fish	5	0.62
14	Weigh sauce	4	0.53
15	Clean & transport	3	0.49
16	Vacuum seal	1	0.91
17	Heat seal	1	1.14
18	Mark pouch, placement, Transport I, fill retort, take out, fill retort, take out	1	0.65
	Total	**18**	**5.19**

Table 4.19 indicates that workstations 11 and 18 now contain more than one job. The Transport G job, the weighing and mixing jobs, and the Transport H job were assigned to the one employee operating workstation 11. The three activities are successive to one another and have a combined cycle time of 0.33 min.kg^{-1} (Table 4.19), which is below the takt time of the production line. Furthermore, the combined jobs in workstation 18 amounted to a cycle time per employee of 0.65 min.kg^{-1} (Table 4.19). This cycle time is slightly higher (0.01 min.kg^{-1}) than the takt time of the production line, indicating that this employee might be over-utilised in the long-term. Alternatively, an additional employee could be allocated to workstation 18 so that the cycle time per employee is reduced to 0.33 min.kg^{-1}. However, this will increase the number of employees required, which will have an effect on the labour cost, and it will decrease the line efficiency as the line is more unbalanced. Instead of allocating another employee, employees can be rotated among the workstations in order to avoid unwarranted fatigue.

The total number of employees required by the second line balancing approach was 18 employees and a total cycle time of 5.19 min.kg^{-1} was obtained (Table 4.19), which is almost 1.60 min.kg^{-1} less than the current operations. The bottleneck was identified as workstation 17, the heat seal workstation, with a cycle time of 1.14 min.kg^{-1} (grey shaded row in Table 4.19). Figure 4.9 illustrates that the cycle time of both workstations 16 (0.91 min.kg^{-1}) and 17 (1.14 min.kg^{-1}) exceed the takt time of the production line. As previously mentioned, these workstations are constrained by the amount of equipment available in the facility. Apart from these two workstations, it is seen in Figure 4.9 that the production line is relatively balanced. A moderate line efficiency of 56.71% was obtained through applying the second method, which is a 22.89% increase from the current production operations.

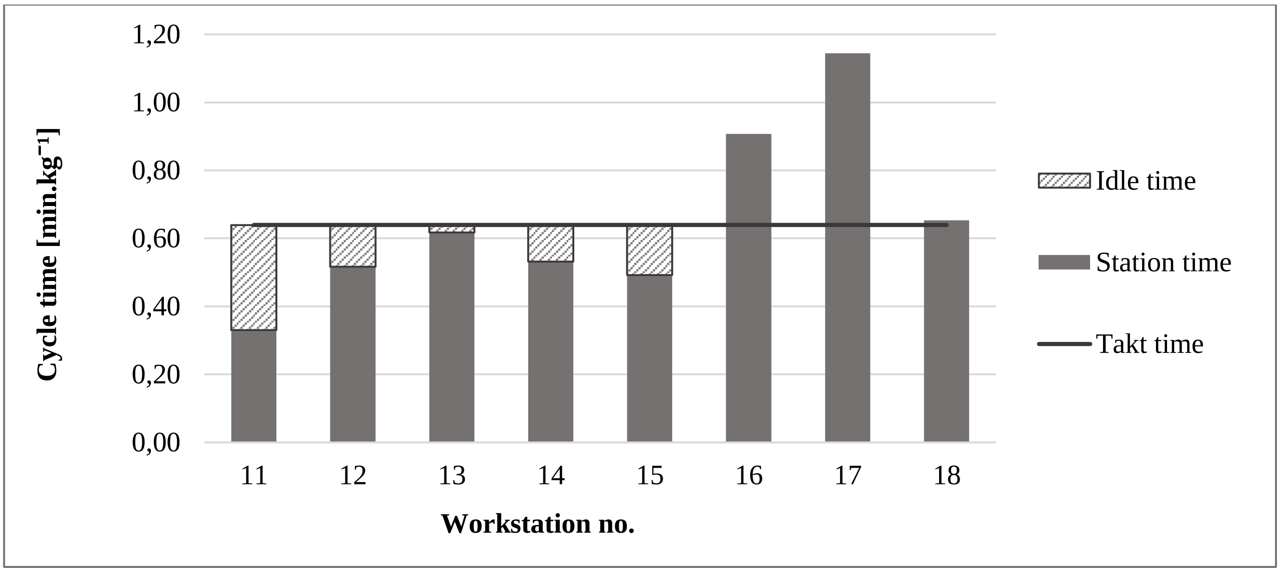

Figure 4.9 Cycle times of workstations in the Le Cap facility resulting from the second LB method relative to the takt time.

Furthermore, the line efficiency obtained from the second method was increased even more by testing a scenario where the current heat and vacuum seal stations are replaced by only one sealing station. This can be achieved by acquiring a more efficient vacuum seal that is able to heat seal the pouch as well. The line efficiency can be increased to 78.57% if two of the more efficient vacuum sealers are added to the line and if an employee is allocated to each. Evidently, the operations resulting from the improved. The total number of employees required by the second line balancing approach was 18 employees and a total cycle time of 5.19 min.kg^{-1} was obtained (Table 4.19), which is almost 1.60 min.kg^{-1} less than the current operations. The line efficiency can be increased to 78.57% if two of the more efficient vacuum sealers are added to the line and if an employee is allocated to each.

Evidently, the operations resulting from the improved second method requires one less workstation and the same amount of employees, however, it poses an additional risk of investment. The cycle time for the new vacuum seal station was taken as the standard time rating of the current vacuum seal. In order to obtain more accurate results, a complete time study should be conducted on the new and changed workstations. Figure 4.10 presents the results obtained for the improved second method, where workstation 16 represents the improved vacuum seal station.

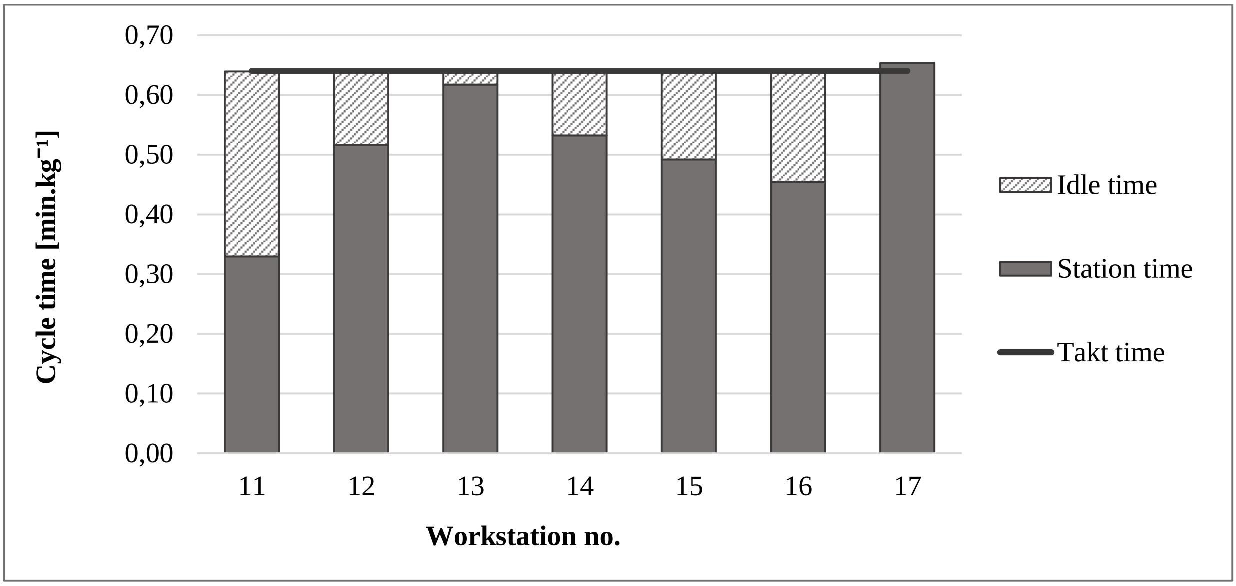

Figure 4.10 Cycle times of workstations in the Le Cap facility resulting from the improved second LB method relative to the takt time.

4.4.2.4 Comparing Current Operations and Proposed Methods

Table 4.20 presents a summary of the results obtained for the current production operation and for the proposed line balancing methods (methods 1 and 2). It must be noted that each new method is an improvement on the previous attempt. However, the risk involved in implementing each of these methods should be considered.

Table 4.20 Comparison between the current production operation and the proposed line balancing methods

Performance indicator	Current operations	Method 1	Method 2	Improved method 2
No. of operators	18	20	18	18
No. of stations	13	13	8	7
Bottleneck cycle time [$min.kg^{-1}$]	1.54	1.14	1.14	0.65
Total cycle time per employee [$min.kg^{-1}$]	6.78	5.77	5.19	3.59
Line efficiency (%)	33.82	38.78	56.71	78.57

The first method is the most simple to implement, as none of the workstations requires significant change. The first method only involved the allocation of more employees to certain workstations so as to increase the capacity and to reduce the cycle time of the bottleneck. In effect, more cost will be spent on direct labour, but overtime costs will be saved as a result of a more efficient production line. Nevertheless, this method yields the lowest reward between the two methods and is ultimately not a major improvement from the current operations.

The second method would be more challenging to implement but results in a 22.89% improvement in the line efficiency. This method is more challenging, as the job description of some workstations are altered. The employees operating workstations 11 and 18 were allocated more than one job, which might be negatively perceived by the employees, due to their workload being increased. The change must be managed effectively in order for the benefits to be realised. The risk of workforce resistance should be mitigated by educating the employees on the need for change in the production line and by actively involving them in the process of change.

Furthermore, the proposed improvement of the second method, which ultimately resulted in a line efficiency of 78.57% (Table 4.20), will not affect the production line employees as much as it will affect the management of the company. An investment into more efficient sealing equipment is required, which means that there is a certain degree of financial risk involved. However, it is important to keep in mind the long-term benefits in terms of productivity and product quality. When ultimately deciding on a control strategy, it is important to consider the risk and rewards associated with each method, as well as the capabilities and goals of the company.

4.5 Value Chain Cost Analysis

The process mapping of the production processes at both the CPUT-based pilot plant and at Le Cap Foods allowed the analysis of the catfish processing value chain. A cost analysis was conducted on the value chain to determine the financial risk related to the product at every step in the production line. The following section will discuss the results obtained for the baseline cost analysis as well as the results obtained for the sensitivity analysis performed on the value chain model. Finally, various risk scenarios was applied in the model.

4.5.1 Baseline Production Costs

The baseline cost of the production operation at both facilities was determined by considering the direct production costs, as indirect production costs were not available from either temporary processing facilities. The results of this study are applicable to a 500 kg batch of whole fish processed into 200 g pouches of fish mince (15% HTVP) mixed with tomato sauce on a manual packaging line. Furthermore, the numbering is similar to the workstation numbering used in the *Line Balancing* section; however, the two production lines were combined for the value chain analysis. The final production step at CPUT is at workstation number 10 and processing at Le Cap starts at workstation 11. Detailed results from the value chain model are presented in Appendix E.

According to Figure 4.11, the total direct production cost of a 500 kg batch amounts to R18270.74. The 500 kg of whole fish theoretically yields 489.35 kg (97.87%) of the fish mince and tomato sauce product, which is approximately 2446 pouches (200 g). Figure 4.11 illustrates a major increase in production costs going from workstation 8 to 9. Workstation 9 involves the mixing of raw materials and the packaging of the product. Evidently, the cost of raw materials and packaging is responsible for increasing the production costs so dramatically. The same can be seen from workstation 13 to 14 and from workstation 15 to 16 (Fig. 4.11).

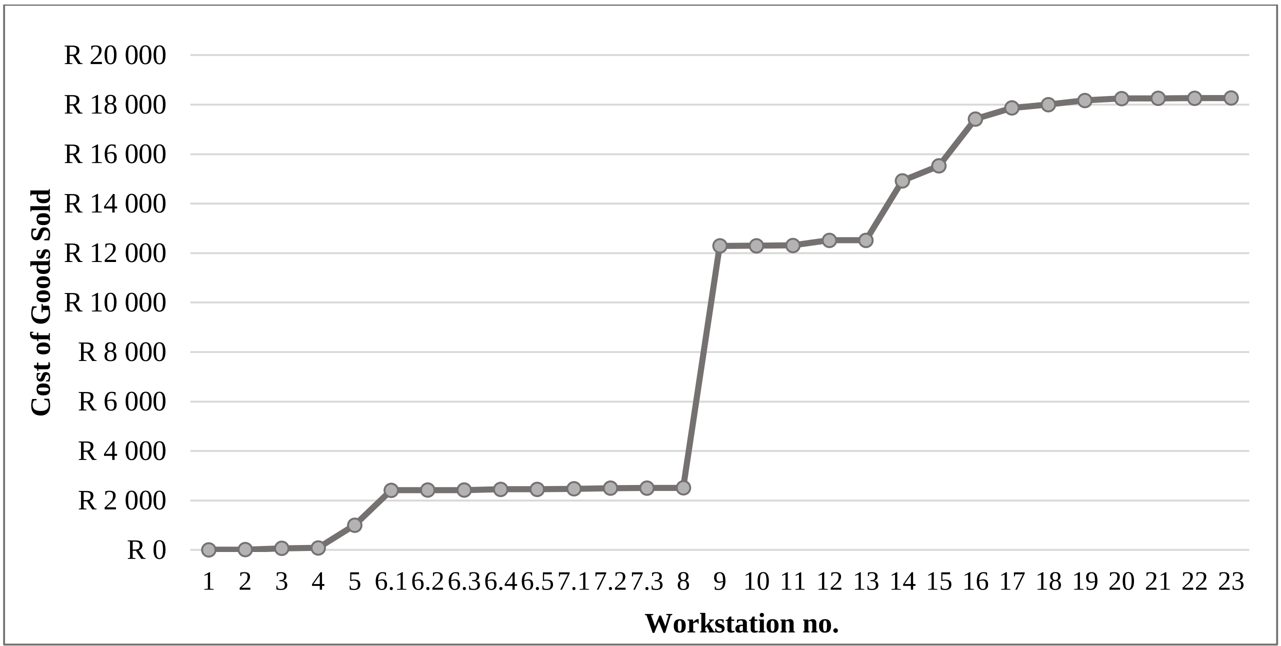

Figure 4.11 Cumulative direct production costs illustrated per workstation.

Figure 4.12 presents the distribution of the direct production cost among the cost elements. Approximately 48% of the direct production cost is attributed to the cost of fish, which is evidently the main ingredient of the fish mince. Labour cost contributes approximately 24% of the total direct cost. It is therefore evident that the most financial risk lies in the raw materials.

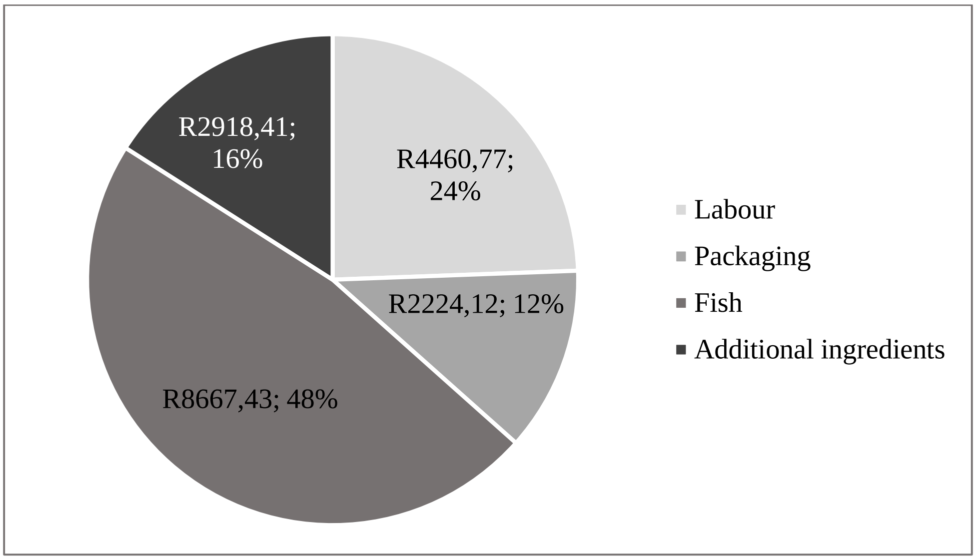

Figure 4.12 Distribution of direct production costs.

Figure 4.13 presents the direct labour cost per workstation. It is evident from the illustration that workstation 6.1 contributes slightly more than R1400 to the labour costs, translating to one-third of the total amount allocated to direct labour costs. In addition, workstation 5 resulted in 20% of the total labour costs. Thus, 50% of the total labour cost goes into eviscerating and filleting the fish. It is, therefore, evident that there is room for improvement in these two steps. If the performance of the operators is improved, a lower standard time rating can be obtained for the workstation, which will directly reduce the labour cost of the production line. A possible control measure for incurring such high labour costs in these two workstations is thus to focus on decreasing the standard times for both workstations by improving the gutting and filleting skills of the employees and by training the employees on the takt time concept which was discussed in the *line balancing* section.

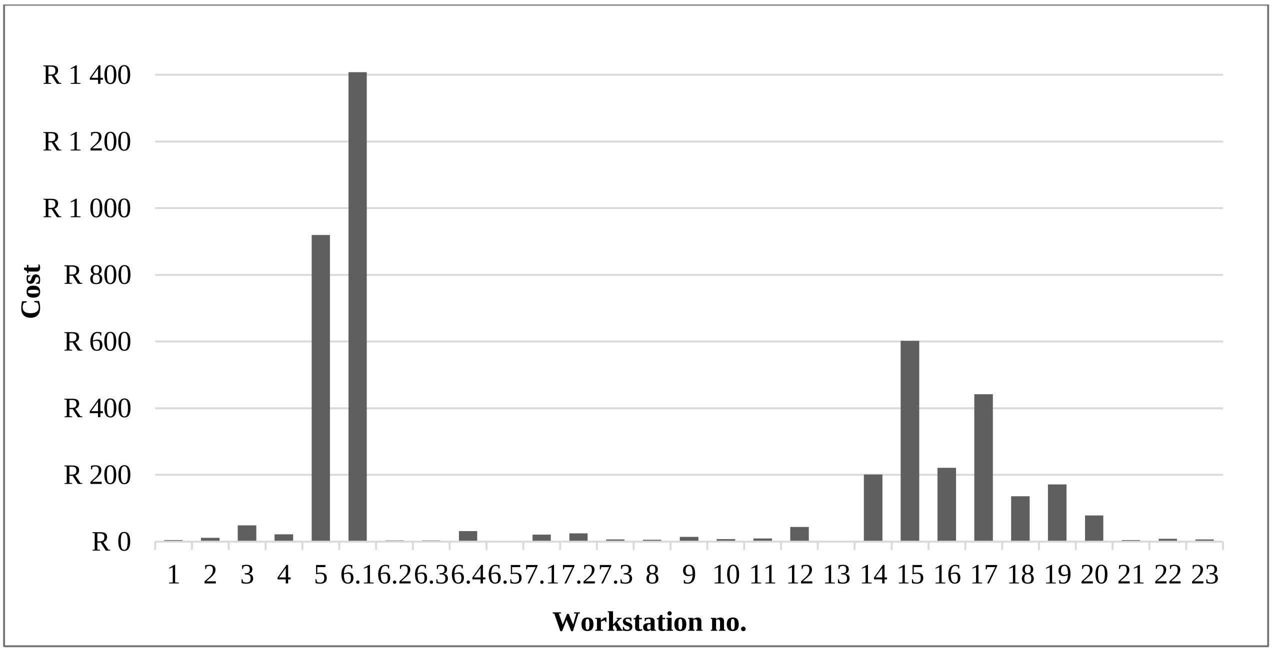

Figure 4.13 Allocation of direct production costs to each processing step in the value chain.

The impact of an improved performance (a decreased ST) was tested by taking the best observed time ratings obtained for both workstations during the time study and converting it to standard time ratings. The greatest standard time rating obtained for workstation 5 was 1.62 $min.kg^{-1}$ and for workstation 6.1 was 2.68 $min.kg^{-1}$. When these standard time ratings were inserted into the model, a reduction of approximately R380 in labour costs was observed, as well as a decrease of 1210 minutes in working time. The amount of money saved is equal to the daily wage of more than two employees. In addition, the saved time can be used to process more product. According to the model, the production line would be able to process 40 kg extra with the additional time before exceeding the daily time constraints.

4.5.2 Flexibility of Value Chain Model

As previously mentioned, the results presented in Figure 4.11 to 4.13 is specific for a batch of 500 kg whole fish processed into 200 g pouches of fish mince (15% HTVP) mixed with tomato sauce. The value chain model is flexible in the sense that the batch size can be changed in order to determine the direct production costs of smaller or larger batches. The model can also accommodate fish mince bases with different HTVP concentrations, as well as products with different sauces and sauce concentrations. Furthermore, the standard time per kilogram rating obtained for each workstation during the time study, allows the model to accommodate the processing of larger pouches as well.

The following sections will discuss the results obtained from the sensitivity analysis of the value chain costing model.

4.5.2.1 Sensitivity Analysis: Batch Size

A sensitivity analysis was conducted by determining the effect of the batch size on the total direct costs or the cost of goods sold (COGS), the total revenue and effectively, the gross profit of the company. Figure 4.14 presents the results obtained.

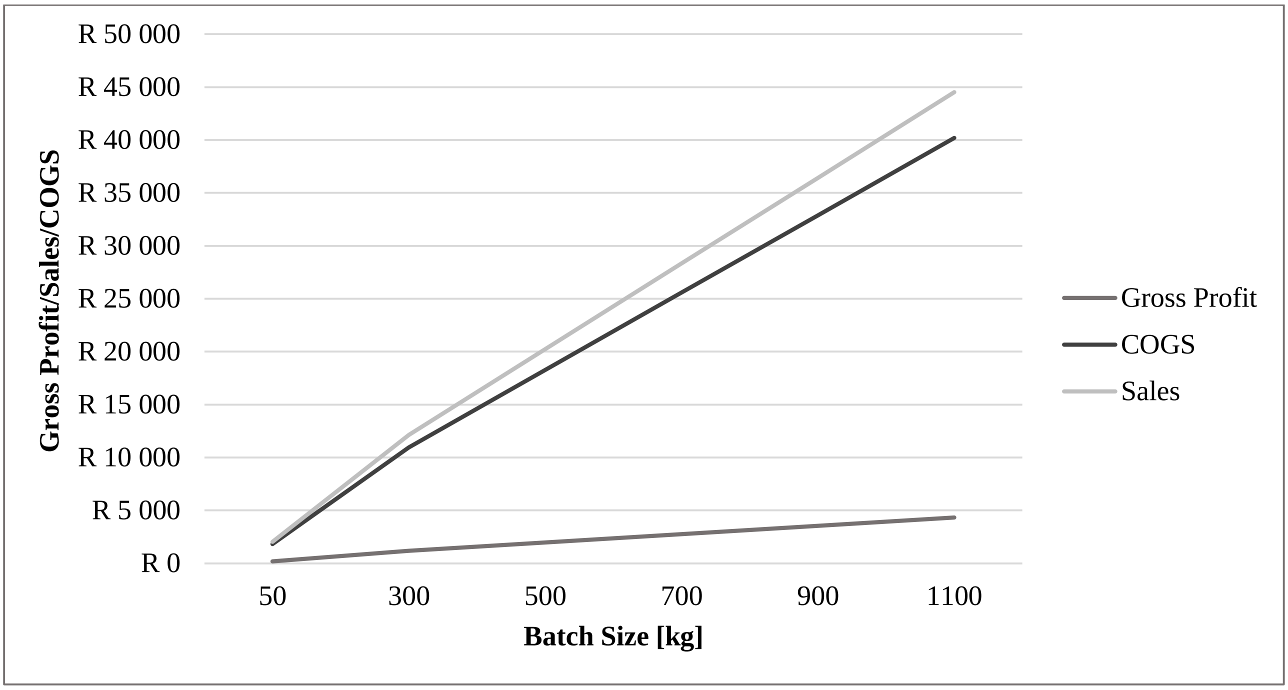

Figure 4.14 Results of the sensitivity analysis conducted on the value chain model in terms of batch size.

It is evident that the gross profit of the company increases linearly with the increase in batch size (Fig. 4.14). However, the profit margin, as well as the capabilities of the facility, should be considered when considering an appropriate batch size. The current capacity of the CPUT pilot plant is 20 employees with seven working hours each. Thus, the total working time available per day is 8400 minutes. In order to process 500 kg of whole fish, approximately 8271.91 working minutes are required, meaning that the facility is almost working at maximum capacity. According to the model, a maximum batch size of 508 kg can be processed per day with the current resources at the CPUT-based pilot plant. A batch size larger than 508 kg will most likely result in overtime and higher production costs. According to the model, for every 200 kg more than 500 kg whole fish, the working hours of seven extra employees are needed on the production line in order for the production deadline to be met. It can, therefore, be said that if the company wants to increase their profit margin, it needs to increase its processing capacity. Increasing the capacity in turn either requires additional staff or more skilled staff. Alternatively, line balancing could be conducted as discussed in the *line balancing* section to decrease the processing time.

4.5.2.2 Sensitivity Analysis: Hydrolysed Textured Vegetable Protein Content

Hydrolysed Textured Vegetable Protein (HTVP) was added to the fish mince in order to increase the profit margin of the product. This sensitivity analysis tested the effect of various HTVP concentration inputs on the direct production costs per kilogram product. The production cost per 200 g pouch was also evaluated against the provisional selling price of the pouch. Figure 4.15 illustrates the effect of different HTVP concentrations on the direct costs per kilogram yield. An increased HTVP content leads to a higher total direct cost per batch, however, the cost per kilogram product decreases due to the fact that a larger yield is obtained per batch.

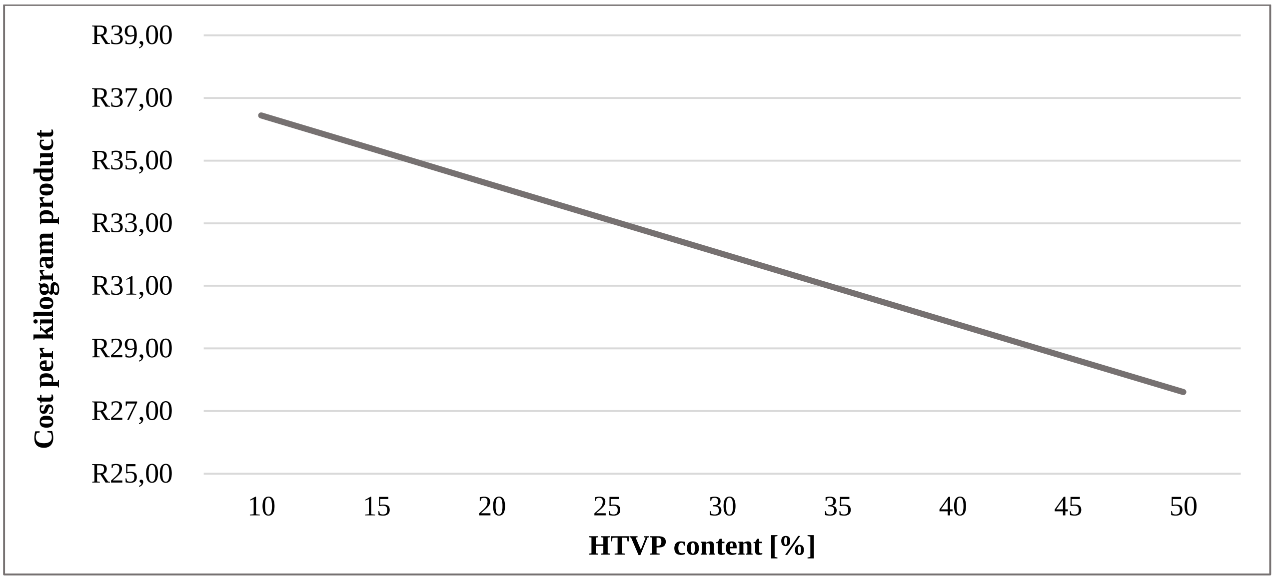

Figure 4.15 The effect of different HTVP concentrations on the cost per kilogram yield.

Figure 4.16 illustrates the degree to which the production cost per pouch is decreased with an increase in HTVP content. Although the direct cost per pouch is less for the product with a 45 % HTVP content, it has a lower profit margin than that of the product with a 15% HTVP content. According to the value chain costing model, the company will make a loss if the 45% HTVP fish mince is sold at its current selling. Evidently, the selling price per pouch should be increased. However, it should be kept in mind that the target market of this product is consumers with a lower Living Standards Measure and therefore the company could potentially lose customers if the price is too high.

It is evident from Figures 4.15 and 4.16 that the financial risk of a batch will decrease if more HTVP is added to the product mix. However, there are regulations to consider that limit the amount of HTVP added to the product. According to the Compulsory Specification for the Manufacture, Production, Processing, and Treatment of Canned Fish, Canned Marine Molluscs, and Canned Crustaceans (Republic of South Africa, 2004:34), soya may not be added to the minced fish if the sole purpose of the addition is to replace the required fish content. Therefore, it is important to consider the functional purpose of the HTVP as well as the nutritional value of the final product when deciding on the HTVP content.

In addition, the Compulsory Specification (Republic of South Africa, 2004:44) states that the minced fish product is not allowed to contain more than 5% starch. The HTVP is not the only ingredient that may add starch to the product, for instance, the sauce as well as the stabilisers may also contribute to the starch content. According to Banaszkiewicz (2011), defatted soy flour (essentially HTVP) has a low starch content of approximately 6.30 %. A theoretical evaluation of the starch content in the fish mince was conducted by means of the value chain. According to the value chain model, a HTVP concentration of 84% and above will cause the plain fish mince (without sauce and thickeners) to exceed the compulsory specification of 5% starch. Therefore, a theoretical estimate of the starch content can be obtained from the value chain model, however, the starch content of the final product or recipe should be determined by implementing the SANS 6317 method (Republic of South Africa, 2004:80) on the production line.

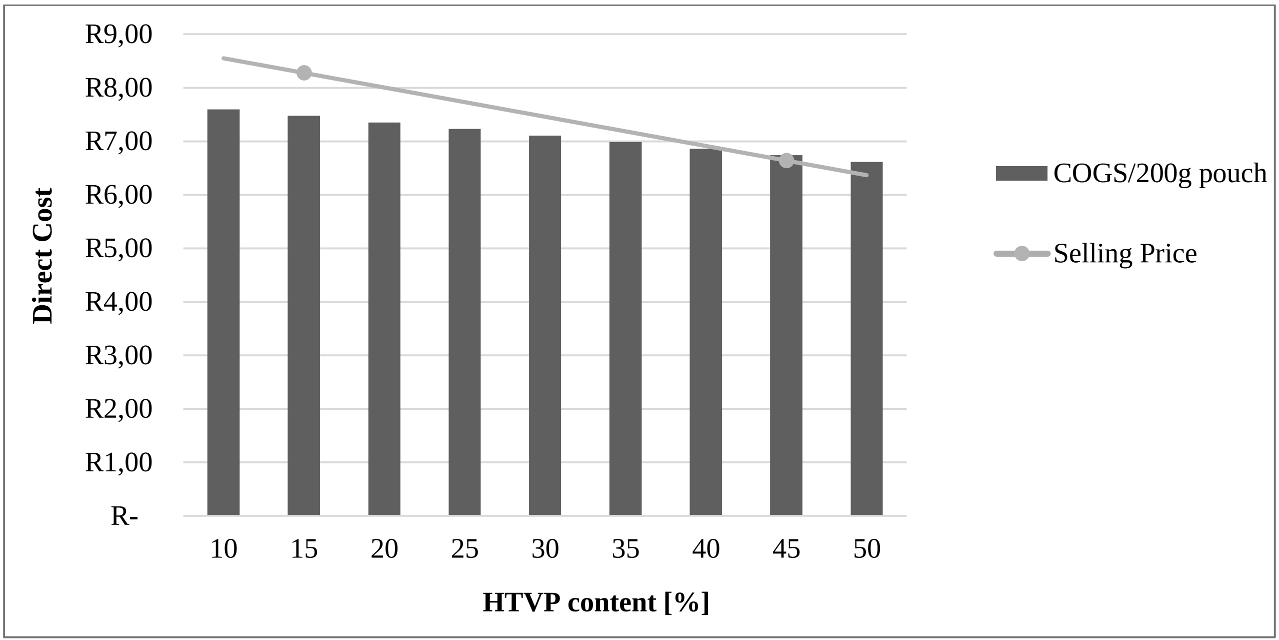

Figure 4.16 The effect of HTVP content on the direct cost per pouch (200 g) produced.

4.5.3 Application of the Value Chain Model to Determine Financial Risk

The value chain model was used to determine the financial risk posed by different risk scenarios identified in the processing facility. The following section will discuss the results obtained from the value chain model.

4.5.3.1 Scenario 1: Pouch is Sealed Improperly According to NRCS Standards

The financial impact of an improper seal was investigated by means of the value chain model. According to the formulated model, the financial impact of an improper seal involves the direct production costs consumed by the product up until the point of rejection. In this scenario, the product was rejected during the final seal integrity check, after the product has left the retort. The batch size of this scenario was chosen as 1000 kg. According to the value chain model, the cumulative production cost up until the point of rejection, is R35 494.81. In addition, according to the HACCP plan, the probability of a microbial hazard occurring from an improperly sealed pouch after the product has left the retort is “not likely”. According to Table 3.2, a probability weight of 0 to 0.25 can be given to such a scenario. A probability of 0.25 was chosen, as the pouches were sealed manually and thus, human error was possible. The financial risk posed by a microbiological hazard resulting from an improper seal for a batch of 1000 kg whole catfish, was calculated by employing equation (12):

$$Financial\ risk = R35\ 494.81\ \times 0.25 = R8\ 873.70$$

However, it should be noted that if the risk occurs as proposed by scenario 1, the cost impact would, in fact, be R35 494.81. The purpose of calculating the financial risk is to provide management with an idea of how much funds to allocate to address this specific production risk. It is evident that the financial impact of an improper seal would be moderate, and should be controlled accordingly. This risk can be avoided by implementing the control measures stated in the HACCP plan, as well as the monitoring and verification procedures involved at the heat seal station. It is the responsibility of the managers and supervisors to keep records and to ensure that these procedures are implemented and that the maintenance plan for the equipment is up to date.

4.5.3.2 Scenario 2: Temperature of Product Increased by more than 12ºC during the Comitrol Process

According to the HACCP plan, there is a risk of microbiological growth if the product temperature increases with more than 12^{0}C during processing. In the event of the temperature of the product increasing more than 12^{0}C, the product should be handled as a non-conforming product, and essentially, be discarded. In order to determine the financial risk of such an event, the processing batch was determined. This event will however not affect the whole batch of fish, but only the batch of softs being processed at that time. During observation, it was established that the softs are usually put through the Comitrol in batches of 30 kg; therefore, it is assumed that 30 kg of softs will be affected by the occurrence of this risk.

Furthermore, the direct production cost of producing 30 kg of softs was determined by means of the value chain model. According to the model, 135 kg of whole fish needs to be processed in order to produce 30 kg of softs. A production cost at the split point in the production line was allocated to each product according to its weight. In Appendix A.1, it is evident that the organs, which form part of the softs, is separated from the other components at the evisceration process (workstation 5, Fig. 4.5). The cumulative production cost up until the evisceration workstation was allocated to the organs and the rest of the components according to their weight. The following calculation was made to obtain the production cost up until workstation 5 specifically for the organs for a batch size of 135 kg:

$$Production\ cost\ attributed\ to\ organs = \ R271.75 \times \frac{6.03\ \%}{97.71\ \%} = R16.77$$

Where R271.75 is the cumulative cost for a batch of 135 kg of fish up to workstation 5, 6.03% is the theoretical yield of the organs (Table 4.5) and 97.71% is the sum of the theoretical yields of the organs, the pet food (Table 4.6) and the remainder of fish. The same calculation was performed for the remainder of the fish:

$$Production\ cost\ attributed\ to\ remainder\ of\ fish = \ R271.75 \times \frac{61.13\ \%}{97.71\ \%} = R170.01$$

As seen in the calculations above, the cumulative production cost attributed to the organs is R16.77 and to the remaining body of the fish after workstation 5 is R170.01. The remaining activity cost is attributed to the pet food components also produced at workstation 5. Appendix A.1 reveals that the back-bone and the side fins are separated from the fillets at the fin trimming and filleting workstation (workstation 6.1). The same calculation as above was performed to determine the production costs attributed to the side fins and the back-bone at workstation 6.1 of a 130 kg batch:

$$Production\ cost\ attributed\ to\ back - bone\ \&\ side\ fins = \ R380.08\ \times \frac{16.21\ \%}{60.78\ \%} = R101.37$$

Where R380.08 is the total production cost of only workstation 6.1, 16.21% is the theoretical yield of the side fins and the back-bone (Table 4.5), and 60.78% is the sum of the theoretical yields of the side fins, the back-bone and the fillets with skin. The total activity cost of workstation 6.2 (6mm Mincer), 6.3 (Transport B) and workstation 6.4 (Comitrol) was also obtained from the value chain model for a 130 kg batch. Thus, the financial impact of discarding 30 kg of softs after the Comitrol station was calculated as:

$$Production\ cost\ of\ 30\ kg\ softs = R16.77 + R170.01 + R101.37 + R0.92 + R1.04 + R8.39 = R298.50$$

The probability of a microbiological growth occurring due to non-conforming processing temperatures was obtained from the HACCP plan and was established as “small”. The term “small” was converted to a probability of 0.3 by using Table 3.2 as a reference. Thus, the financial risk was calculated by employing equation (12) as follows:

$$Financial\ risk = R298.76 \times 0.3 = R89.63$$

Thus, the financial risk posed by the occurrence of non-conforming processing temperatures is relatively small. However, due to the fact that there is financial risk involved, the risk should be monitored by completing the Process Control and Product Release Form.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Achievement of research objectives

The most important thing for Blue Karoo Trust, and any other emerging company in the aquaculture industry, is for their production operations to become commercially viable. The aquaculture industry has a history of failed projects due to poor planning, poor execution, and a lack of proper risk management. In South Africa, a successful, commercial catfish processing facility will have major social, environmental and economic benefits, indicating that it is essential to identify risks that could hinder the success of such a project.

The development of the risk management framework for the catfish processing pilot plant had three major objectives. The first was to develop a risk management framework that aligns with the quality and safety management system of the processing facility. This research objective was achieved by first investigating risk management frameworks developed by different industries, as well as the risk management techniques previously employed in the food industry. This objective was essentially achieved by the literature review in the second chapter. The most appropriate aspects of all the frameworks investigated in literature were combined in order to obtain a risk management framework that integrates with the quality and safety management system of the catfish processing plant (Fig 5.1).

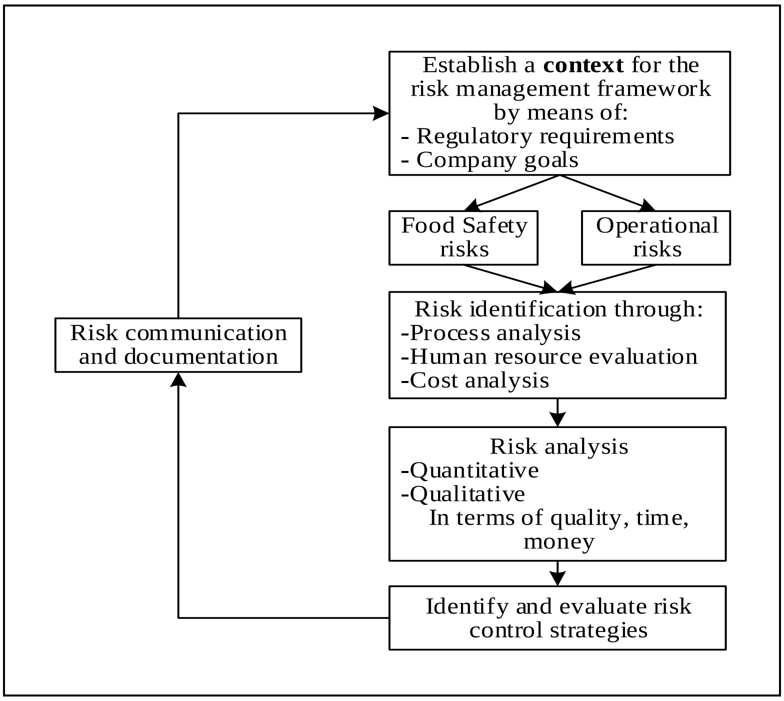

Figure 5.1 Proposed risk management framework for the catfish processing pilot plant.

The second research objective was to identify risks in the pilot plant and to suggest appropriate control strategies. Risk identification methodologies were proposed and data was obtained from the employees and processes at the pilot plant. The quality of data obtained at the pilot plant was questionable, due to the unstable and unpredictable circumstances in which the pilot plant operated. However, this research report did not aim to provide statistically valid results to the company in question. The aim was to provide a methodology for identifying risks of various nature, and to propose control strategies based on the outcome of the implemented methods. The data analysis of the example data obtained from the pilot plant operations led to the identification of events that could have an impact on product quality, production time and/or the financial performance of the company when not effectively controlled. Appropriate control strategies were recommended and in this way, the second research objective was met.

Finally, a value chain model was developed that incorporated all the information and data obtained from the pilot plant. A sensitivity analysis was conducted on the value chain model to determine which production factors require the most control in terms of financial risk. These factors would be considered when the pilot plant eventually moves to the full-scale production facility in Graaff-Reinet. The third research objective was met through this analysis. As the three research objectives were met, it can be argued that the research problem was addressed sufficiently and that the framework is able to identify and control risks in the catfish processing facility of Blue Karoo Trust.

5.2 Recommendations

It was previously mentioned that the circumstances in which the data for this study was obtained, was not ideal. It is therefore necessary to make the following recommendations with regard to the application of the proposed risk management system:

i. Little data was available in terms of actual production yield and waste. It is recommended that effective records be kept of this data in order to have a database over time, and thus a more accurate indication of yield losses in the facility.
ii. Due to time and practical limitations, the proposed line balancing methods could not be implemented and tested on the production line. Due to this limitation, accurate activity time data could not be established for the proposed methods. It is, therefore suggested that additional time studies be conducted on the altered production lines to obtain more representative results.
iii. Due to lack of information, the value chain does not incorporate fixed production costs. Once this information becomes available, it is recommended that the company incorporate fixed costs into the value chain framework in order to obtain a more accurate representation of the overall production costs and production cost per unit.
iv. A more accurate representation of the takt time of the production line should be determined once an average customer demand is established.

v. A complete mass balance study should be conducted for fish that are significantly larger or smaller than 1 kg (± 0.109 kg), as assumptions were made based on the average weight of the components of a 1 kg fish (± 0.109 kg). The size and mass of the components of a larger fish may differ.

vi. This study solely focussed on identifying internal risks related to the catfish processing facility. However, a start-up company has numerous external risks to consider as well. It is therefore recommended that further studies be conducted on appropriate external risks related to a company that processes catfish or other farmed fish species.

In addition, the following recommendations are made based on the risks identified in the current operations of the catfish processing pilot plant:

i. It is recommended that the company create a budget and schedule for continuously educating and training employees on GMP and HACCP systems that are specific to the catfish processing facility.

ii. The company should implement HACCP incrementally in the pilot plant to facilitate HACCP implementation in the commercial scale plant. One suggestion is to start with the recording of processing data on the documents provided in the HACCP plan.

iii. It is recommended that the management of the company motivate supervisors to implement food safety principles on the production line by continuously educating them on the importance of these systems and by possibly providing a performance-related incentive.

iv. It is suggested that the company conduct formulation tests on the main product to incorporate more of the "softs" in an attempt to reduce waste on the production line. Alternatively, it is recommended that the pet food recipe be adjusted to incorporate the excess "softs".

v. Management should educate the production line employees on lean production principles and it is suggested that the takt time technique be implemented on the production line in order to increase efficiency.

vi. It is suggested that the employees on the production line be motivated by implementing visual equipment on the production line that displays a countdown for the takt time, as well as the production targets for the day and to what extent it is being met.

vii. It is recommended that BKT constantly strive towards reducing raw material cost without compromising product quality. The ideal approach is to reduce product yield loss on the production line by training employees and by establishing an effective mass-balance database.

6. REFERENCES

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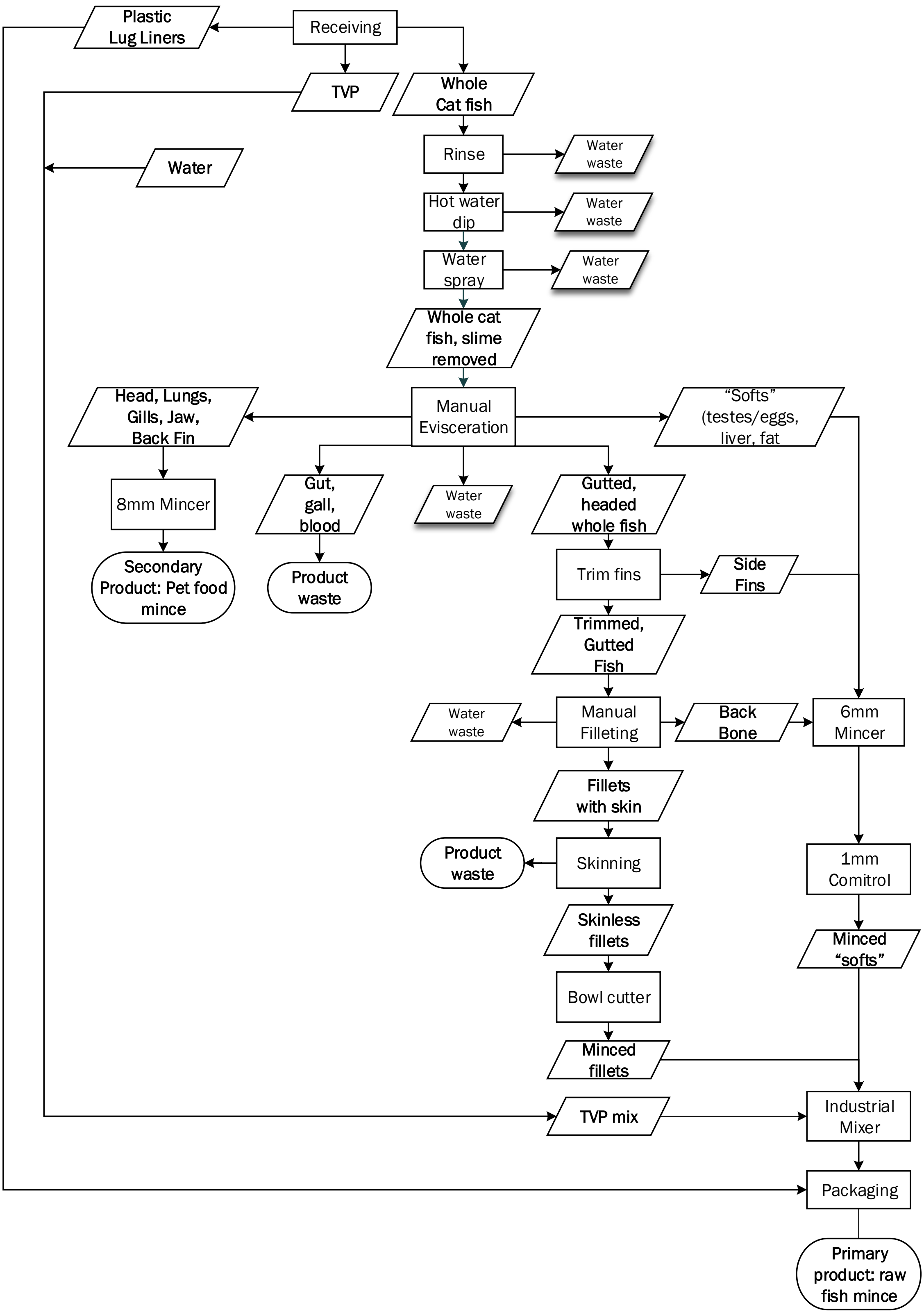
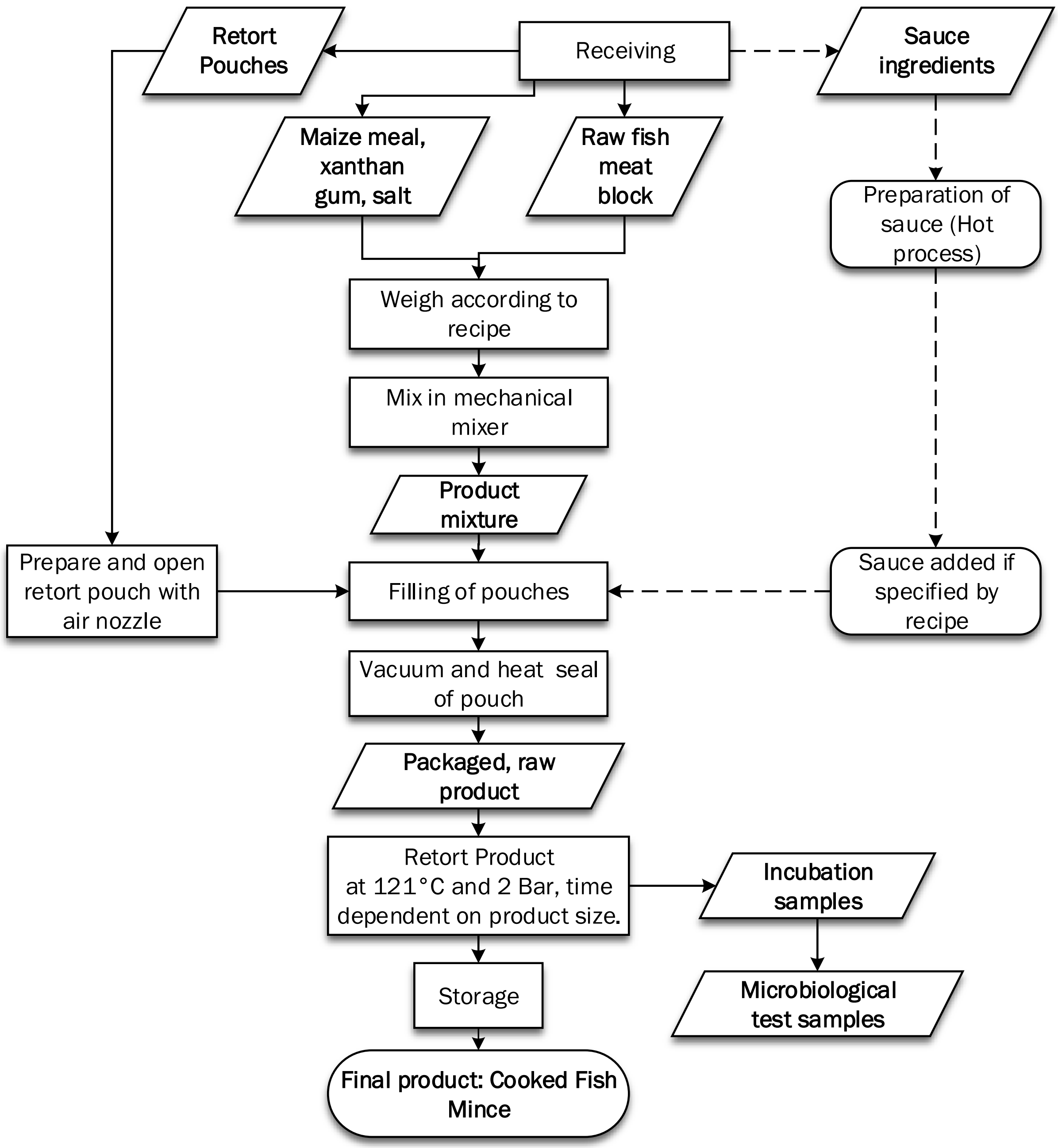
APPENDIX A PROCESS FLOW DIAGRAMS

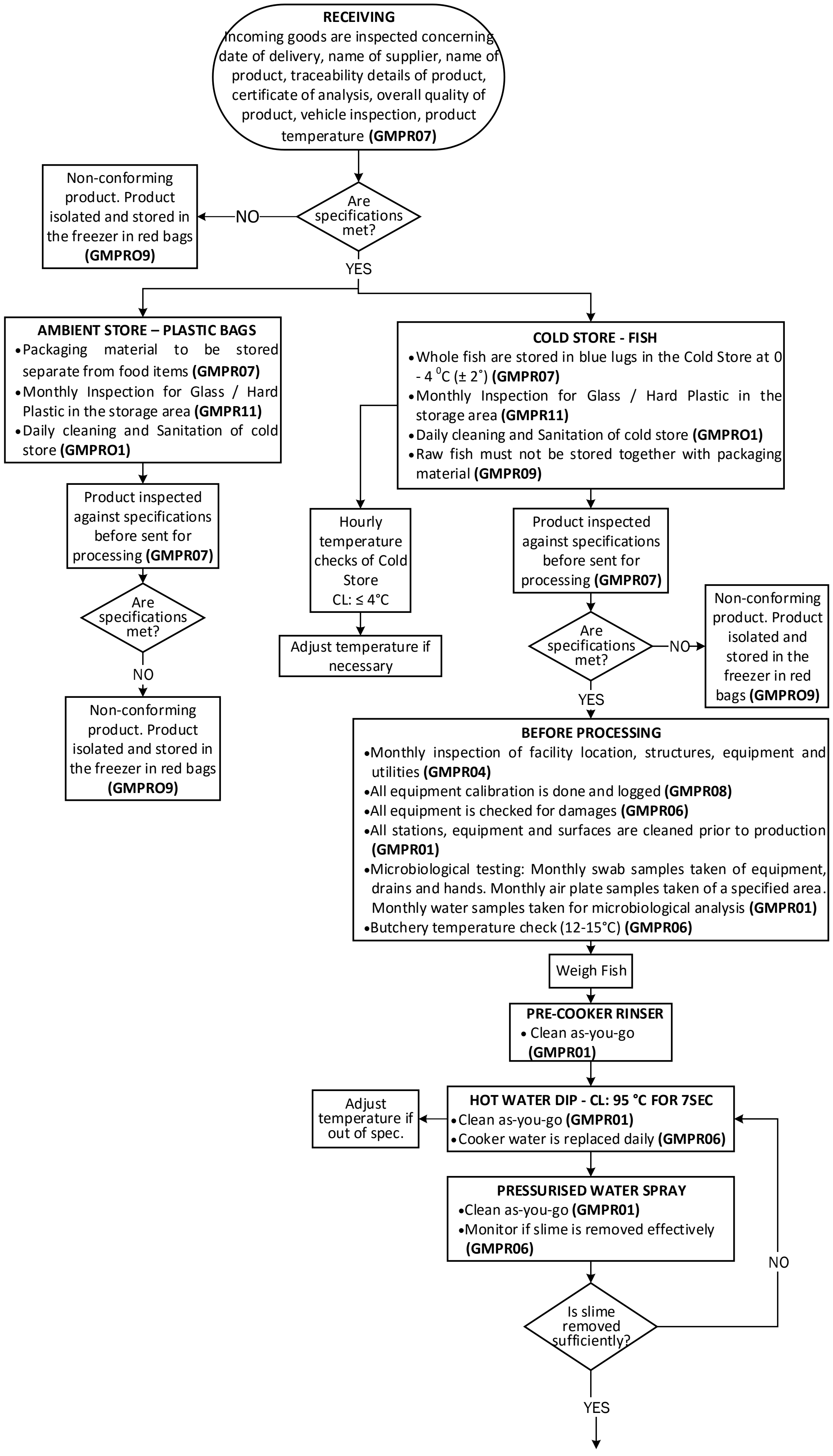
A.1 Material flow at the CPUT-based pilot plant



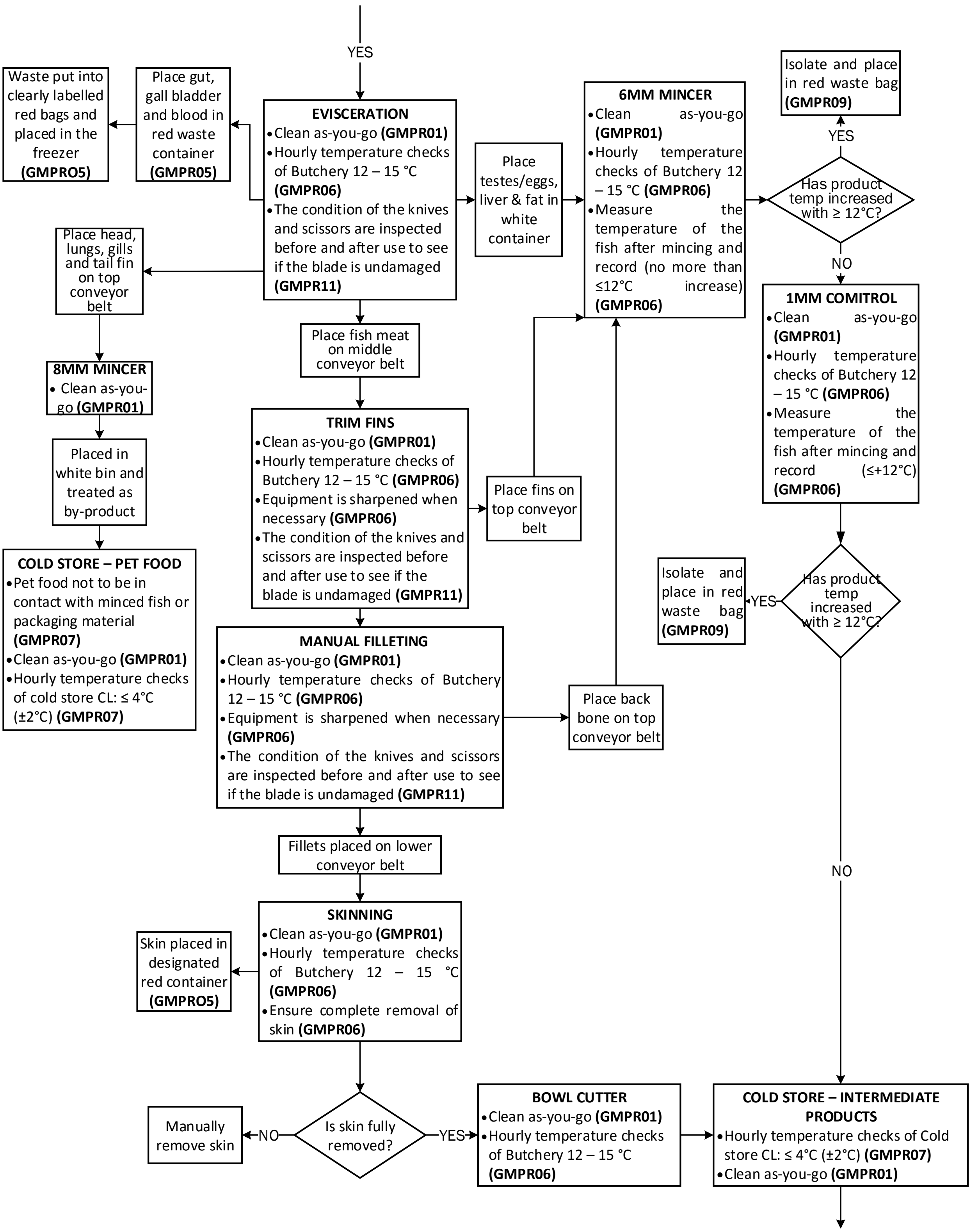
A.2 Material flow at Le Cap Foods processing plant



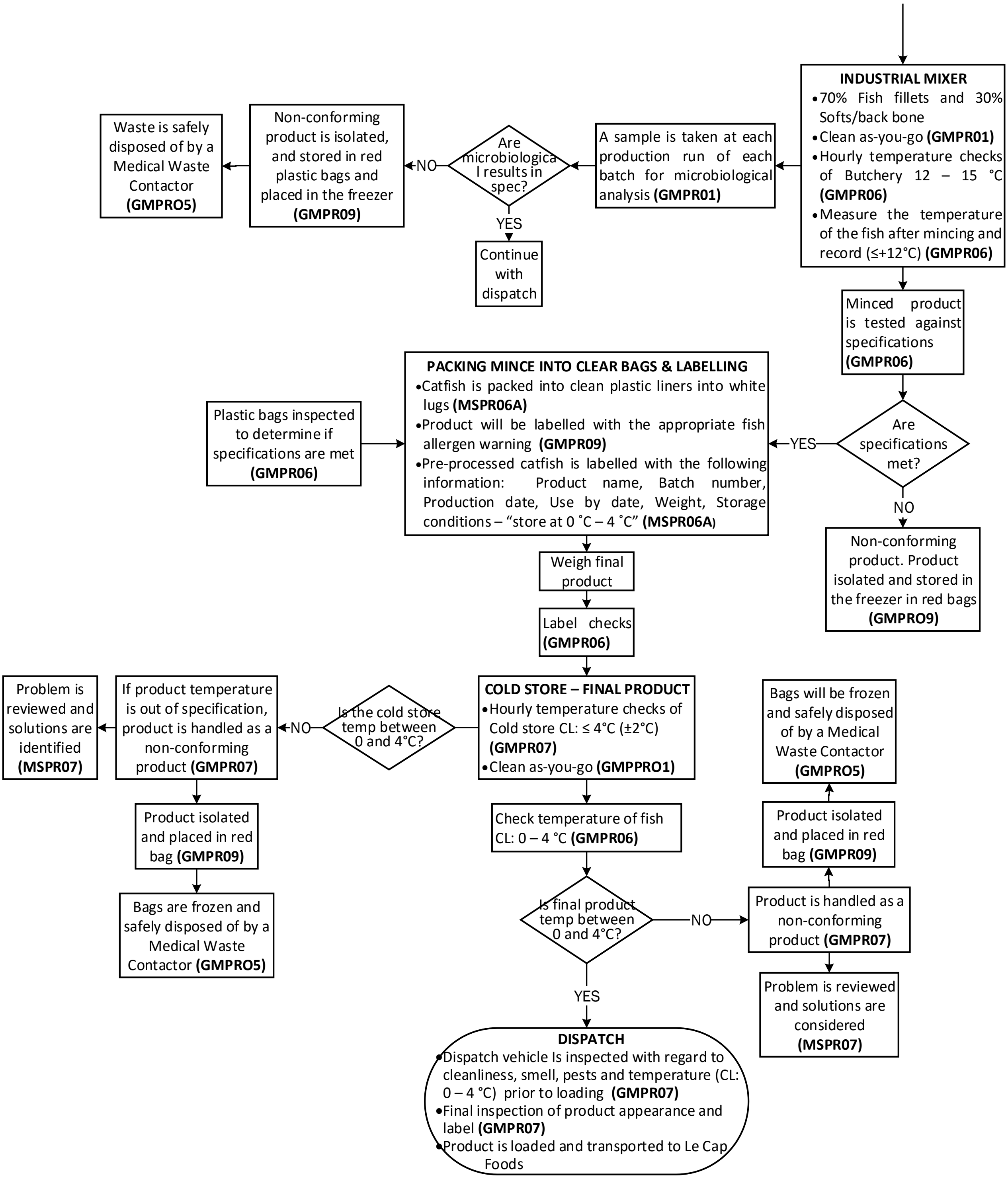
A.3 Detailed process flow diagram of operations in the CPUT-based pilot plant



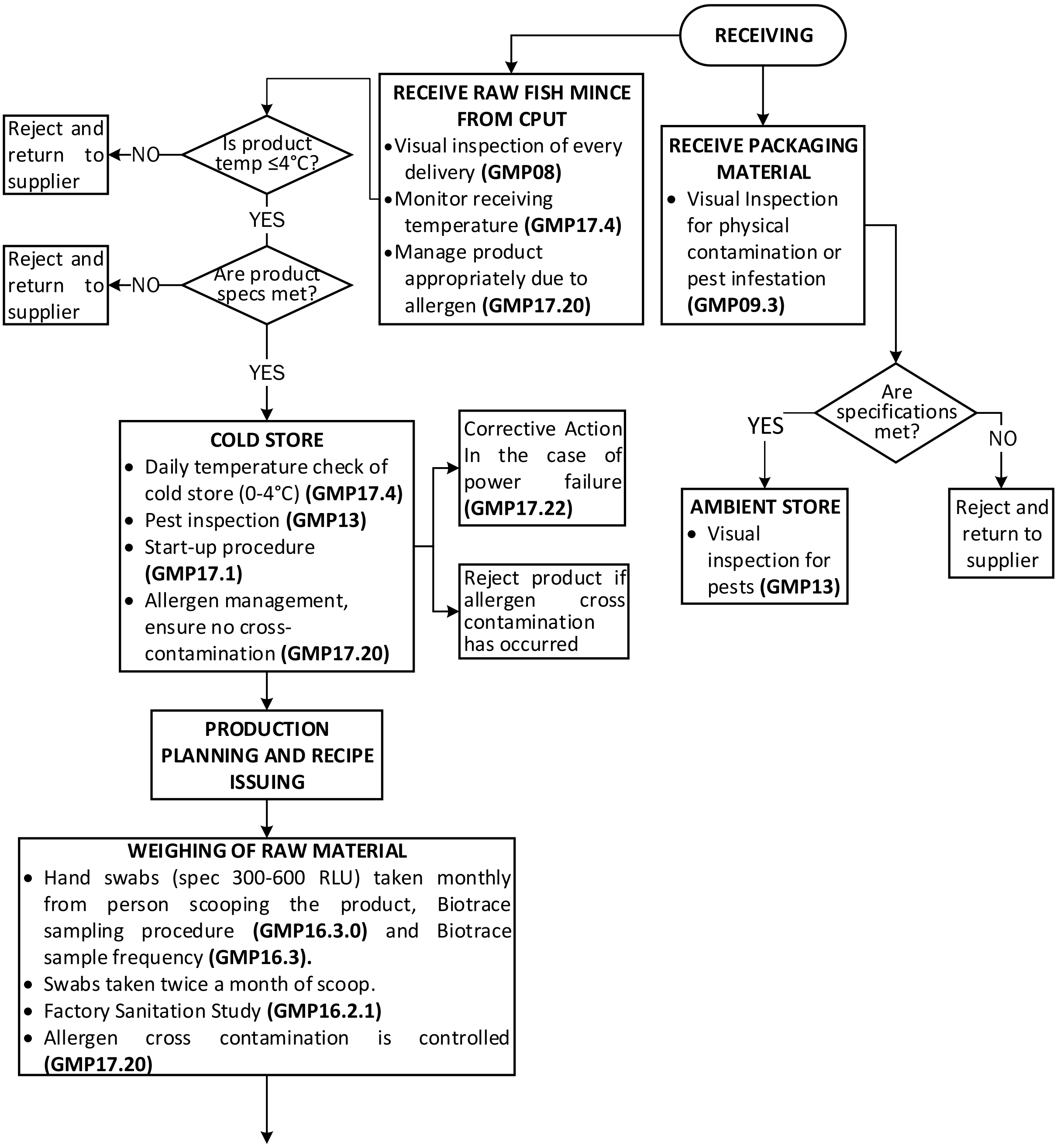
A.3 Detailed process flow diagram of operations in the CPUT-based pilot plant (continue)



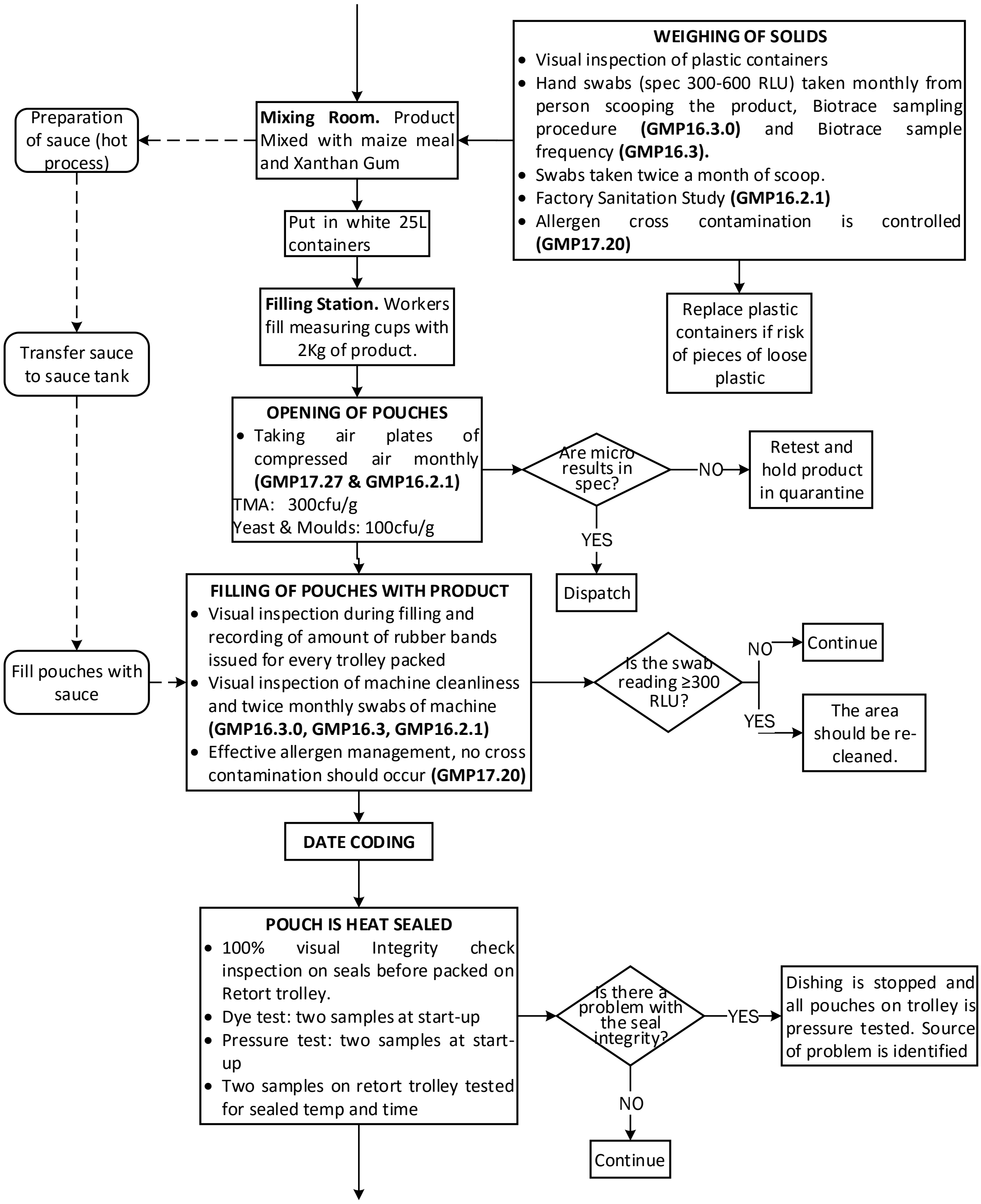
A.3 Detailed process flow diagram of operations in the CPUT-based pilot plant (continue)



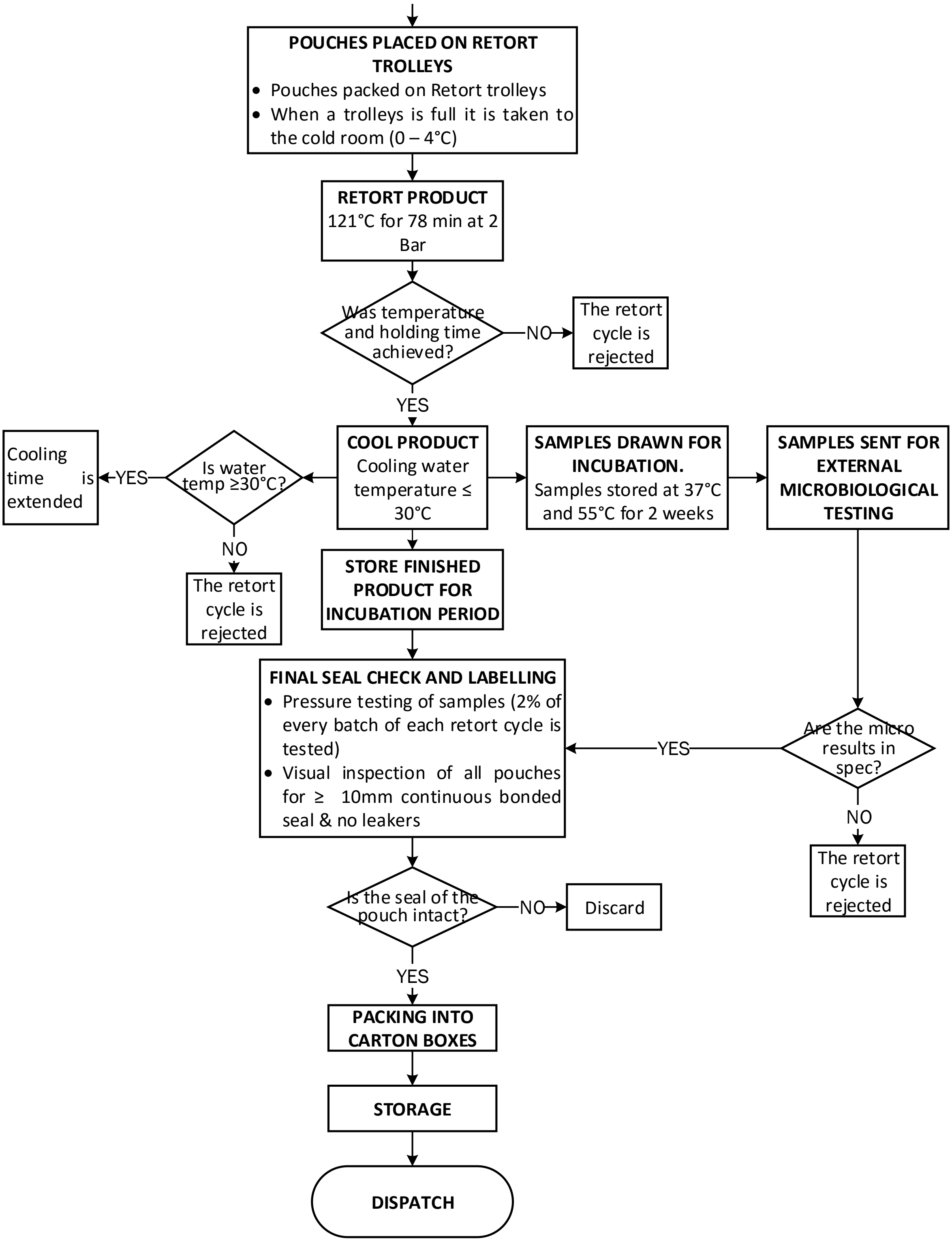
A.4 Detailed process flow diagram of operations in the Le Cap Foods facility



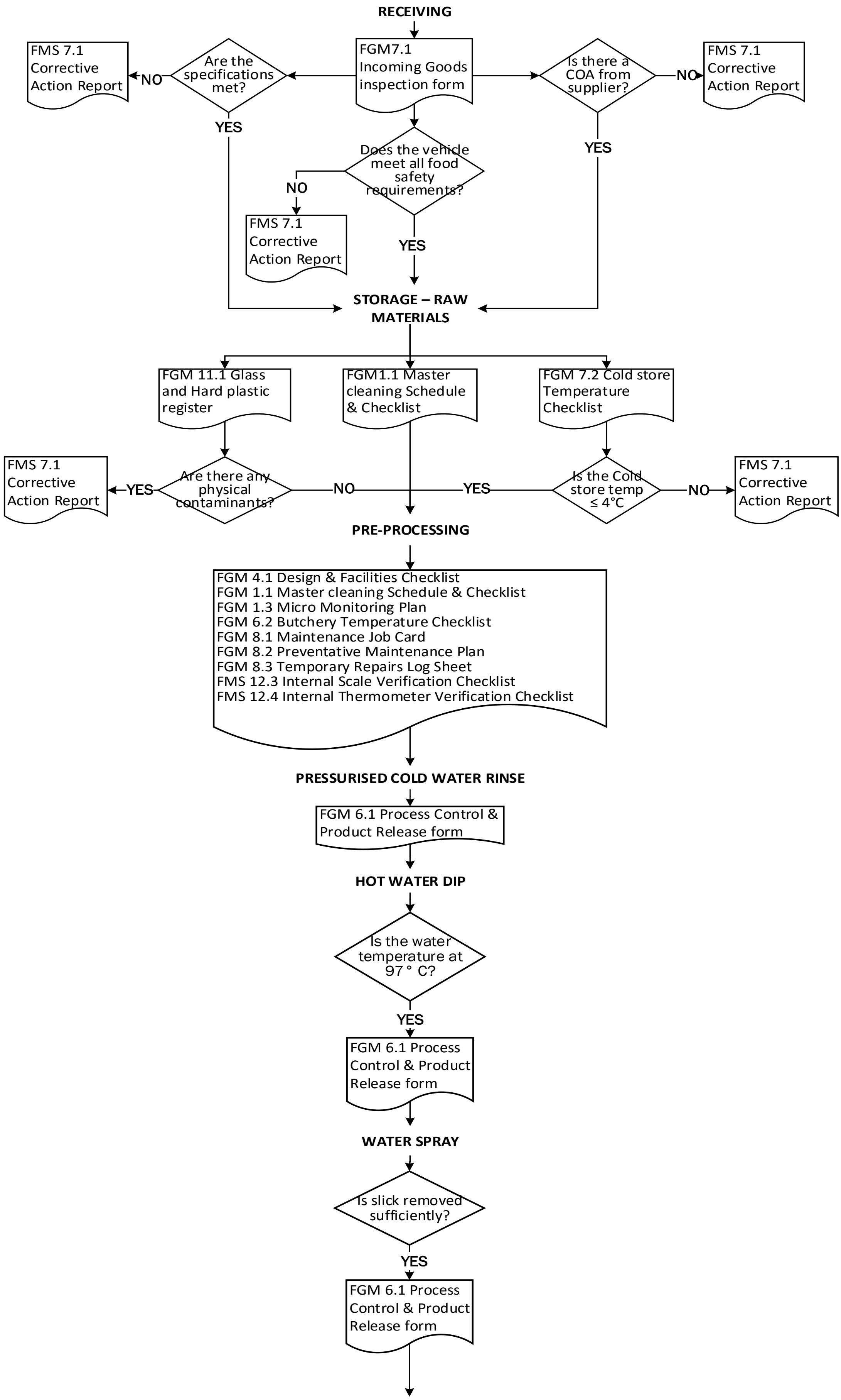
A.4 Detailed process flow diagram of operations in the Le Cap Foods facility (continue)



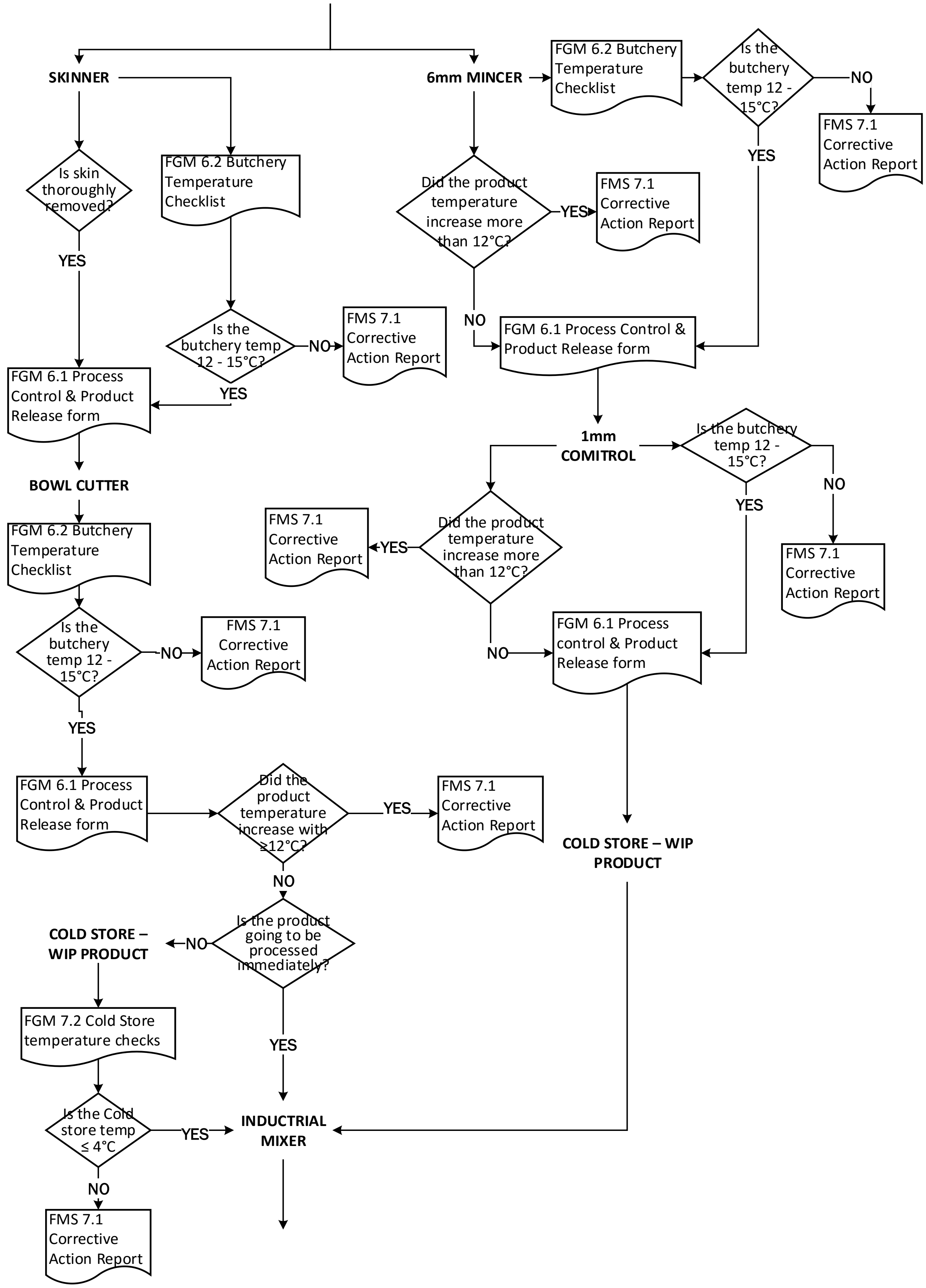
A.4 Detailed process flow diagram of operations in the Le Cap Foods facility (continue)



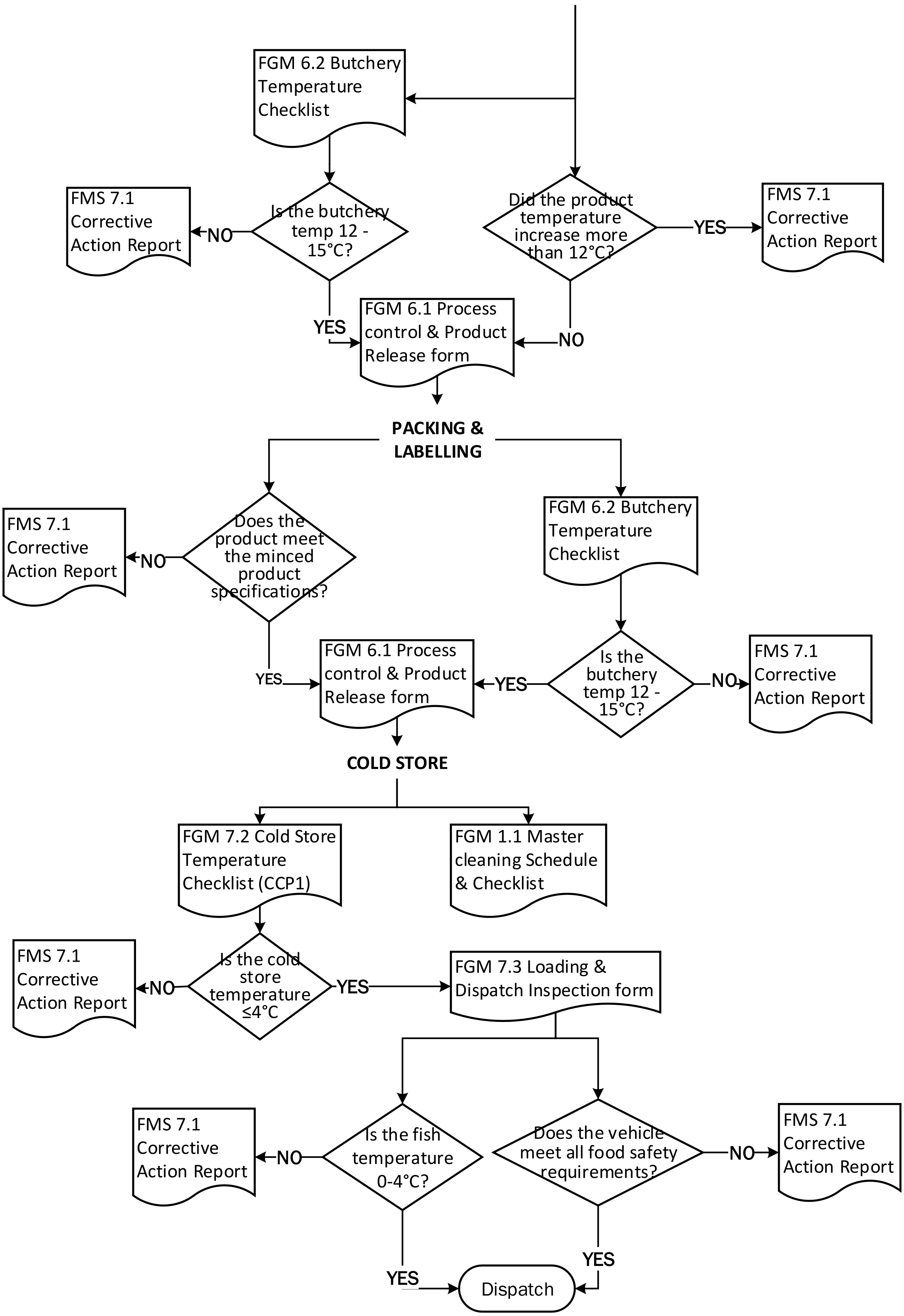
A.5 Documentation/information flow in the CPUT-based pilot plant



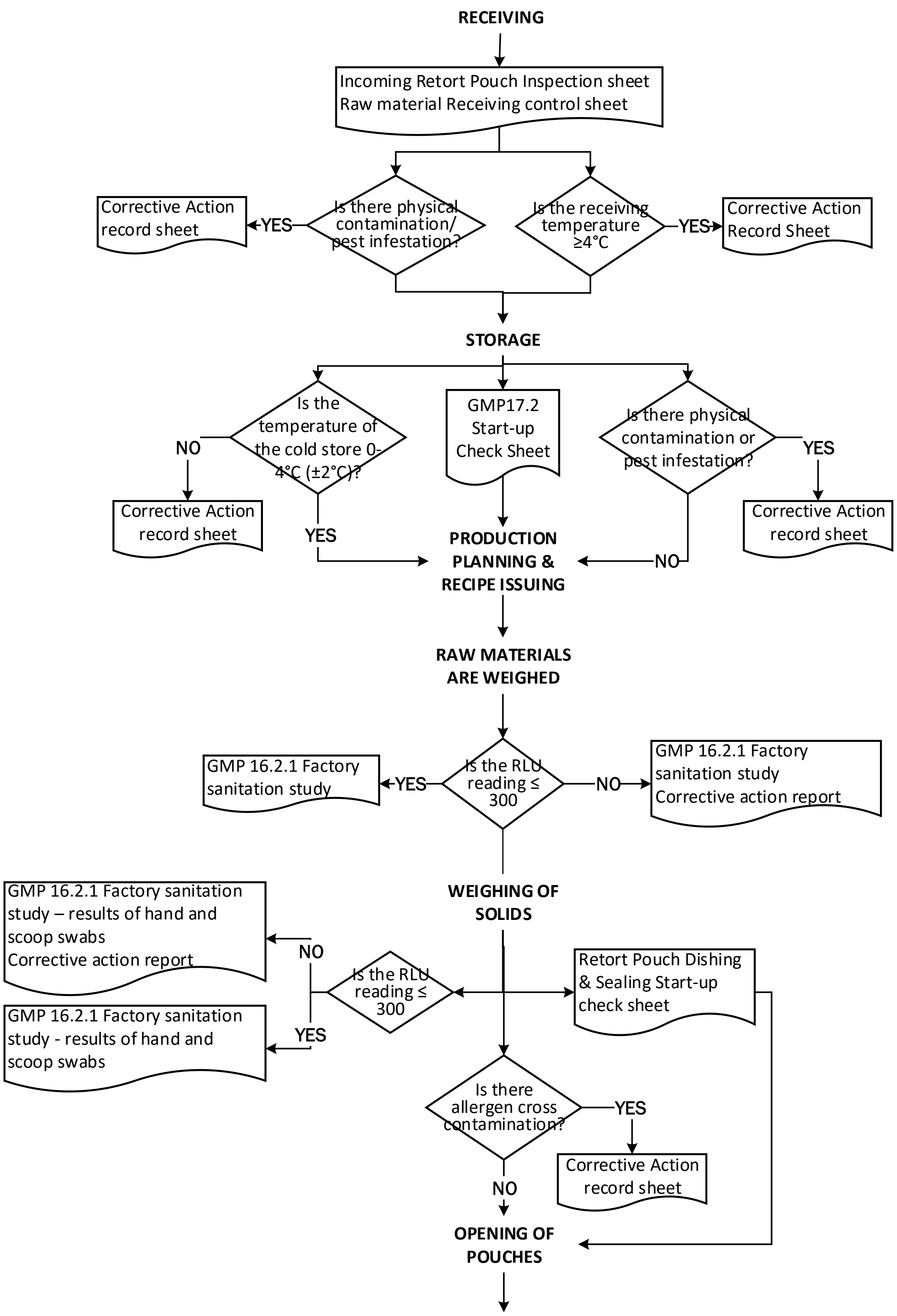
A.5 Documentation/information flow in the CPUT-based pilot plant (continue)



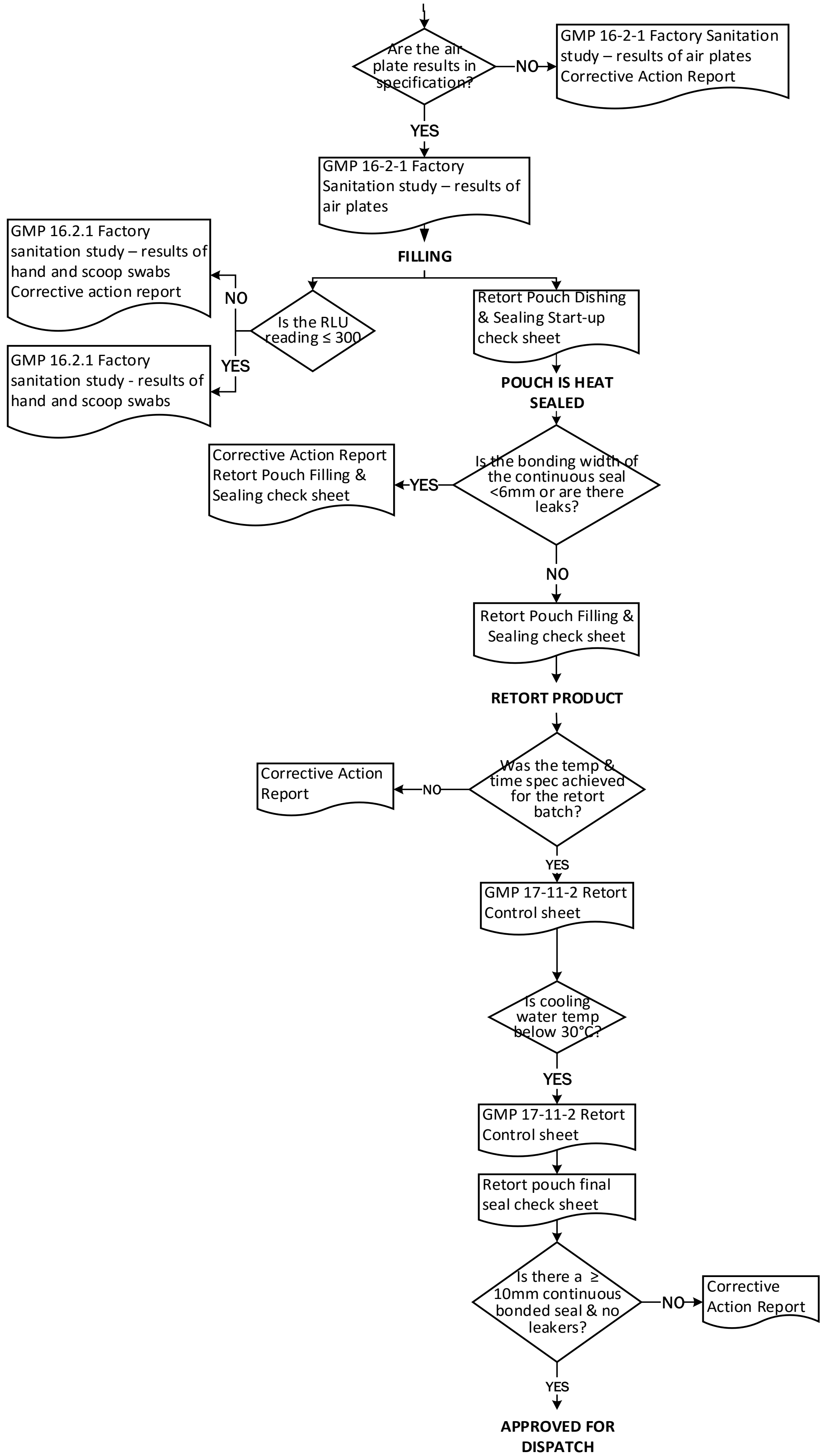
A.5 Documentation/information flow in the CPUT-based pilot plant (continue)



A.6 Documentation/information flow at Le Cap Foods



A.6 Documentation/information flow at Le Cap Foods (continue)



APPENDIX B QUESTIONNAIRES FOR PRODUCTION LINE EMPLOYEES

Answer the following questions by marking the appropriate box with an "X".

1. Catfish is considered a high-risk food product

Disagree	
Agree	

2. When machinery is used to process the fish (e.g. mince or mix), controlling the product temperature is… (choose one)

Not important, as mechanically processing the fish will not influence its temperature	
Not important, as long as the fish is minced to the correct size	
Important, so that the growth of spoilage bacterial can be avoided	
Important, so that the physical quality of the product is managed	

3. The identified CCP in the catfish processing line is the following processing step: (choose one)

Evisceration	
Cold Store of final product	
6mm Mincing	
Packaging	

4. Which one of the following hygiene principles do you think is most important to implement? (choose one)

Washing your hands after visiting the toilet	
Washing your workstation and equipment before a break	
Visual inspection of incoming raw material	
Checking the temperature of the butchery every hour	

5. How would you react if you see a foreign object in the fish mince? (choose one)

I would not do anything	
I would carefully consider what to do and find the best possible solution on my own	
I would consult with my supervisor	
I would immediately carry out necessary measures to correct the situation	
I would consult with my co-workers	
I am not sure	

Answer the following questions by circling the appropriate box.

6. I have to make sure that the food I work with is safe for human consumption.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

7. I think the implementation of HACCP will have a positive effect on the product and the company as a whole.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

8. It is important that I constantly educate myself about food safety.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

9. I think implementing HACCP promotes teamwork.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

10. In the catfish processing plant, there is sufficient time to implement food safety principles.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

11. The supervisors set a good example for the operators concerning hygiene and food safety practices.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

12. When I have a suggestion or comment concerning food safety and hygiene, I can talk to my supervisor about it.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

13. My supervisors communicate regularly with all operators about hygiene and food safety.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

14. It is clear that my supervisors take hygiene and food safety very seriously.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

15. My supervisors handle food safety issues in a constructive and respectful way.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

16. If I had a chance to choose my profession again, I would choose the same thing.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

17. I feel challenged by the work I do in the factory.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

18. The current factory conditions enable me to carry out my duties with regard to food safety principles.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

19. I feel motivated and supported by my co-workers.

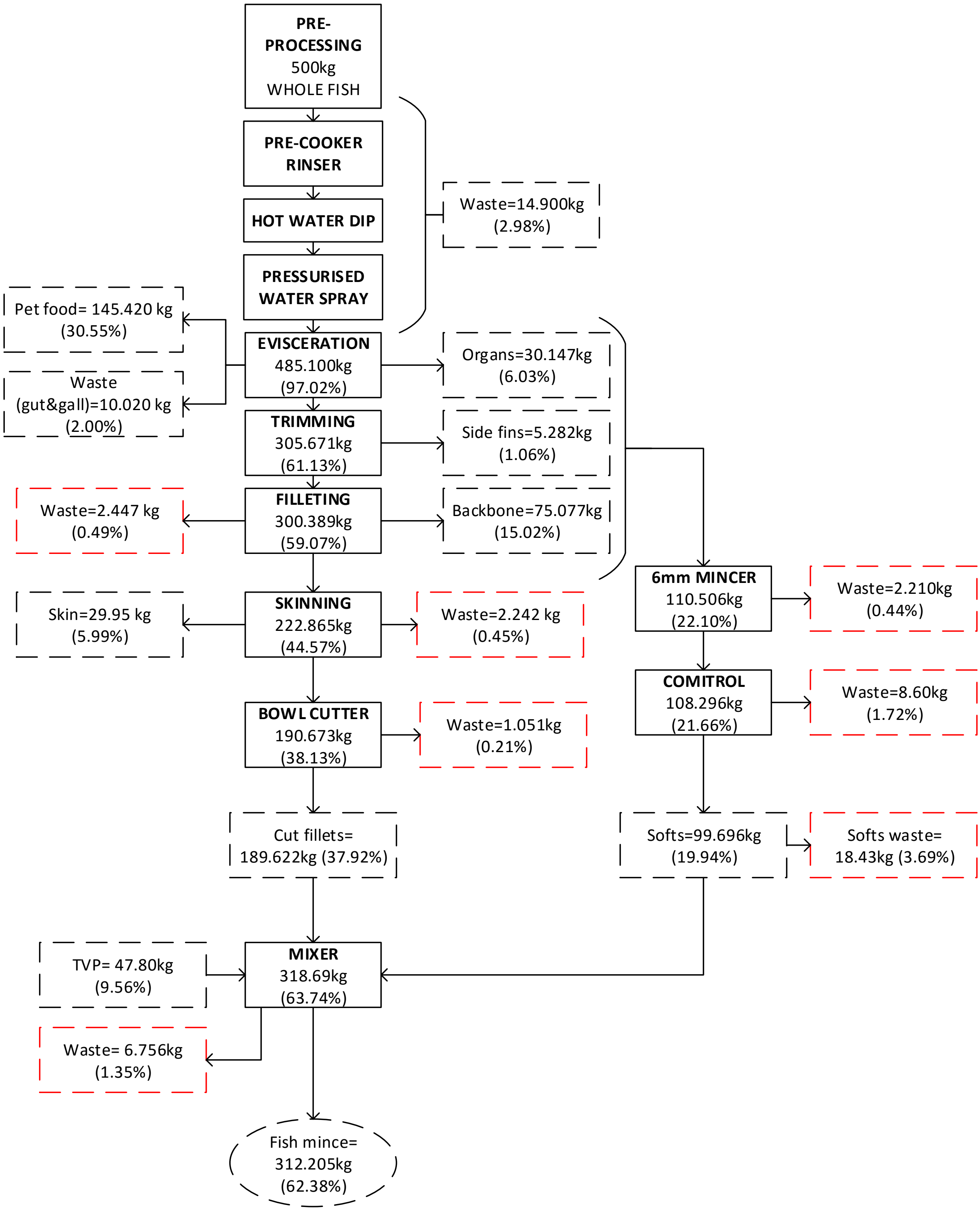
Strongly disagree	Disagree	Not sure	Agree	Strongly agree

20. My co-workers practise good hygiene principals.

Strongly disagree	Disagree	Not sure	Agree	Strongly agree

APPENDIX C MASS BALANCE DIAGARM FOR THE PILOT PLANT AT CPUT

Mass balance for a batch size of 500 kg whole fish.



APPENDIX D RELAXATION ALLOWANCES

D.1 Relaxation allowances for line 1 at the CPUT based pilot plant

Type of strain		**Processing steps in line 1**											
		1	**2**	**3**	**4**	**5**	**6.1**	**7.1**	**7.2**	**7.3**	**8**	**9**	**10**
Variable allowances (points [A])	**A. Physical Strain**												
	Average Force Exerted	20	0	0	0	0	0	0	0	20	20	14	14
	Posture	4	3	3	3	3	3	3	3	4	4	3	4
	Restrictive Clothing	1	0	0	0	1	1	1	1	1	1	1	1
	B. Mental Strain												
	Concentration/Anxiety	0	0	0	0	6	6	0	0	0	0	0	0
	Monotony	0	0	0	0	2	2	1	1	0	0	0	0
	Eye Strain	0	0	0	0	2	2	0	0	0	0	0	0
	C. Strain resulting from environment												
	Wetness	0	1	1	1	1	1	1	0	0	0	0	0
	Total Points	**25**	**4**	**4**	**4**	**15**	**15**	**6**	**5**	**25**	**25**	**18**	**25**
	% Conversion [B]	**14**	**10**	**10**	**10**	**12**	**11**	**10**	**10**	**14**	**14**	**12**	**14**
Special allowances (%)	Unavoidable delays	0	1	0	0	2	0	0	0	0	0	0	0
	Setup	0	0	3	0	0	0	0	0	0	0	0	0
	Tool allowance	0	0	0	0	1	1	0	0	0	0	0	0
Total % allowance per processing step		**14**	**11**	**13**	**10**	**15**	**12**	**10**	**10**	**14**	**14**	**12**	**14**

[A] Points allocated as proposed by the International Labour Office of Switzerland (1992:491-49)

[B] Points conversion table supplied by the International Labour Office of Switzerland (1992:497-498)

D.2 Relaxation allowances for line 3 at the CPUT based pilot plant

Type of Strain		**Processing steps of line 2**			
		6.2	**6.3**	**6.4**	**6.5**
Variable allowances (points [A])	**A. Physical Strain**				
	Average Force Exerted	0	20	0	20
	Posture	3	4	3	4
	Restrictive Clothing	1	1	1	1
	B. Mental Strain				
	Concentration/Anxiety	1	0	1	0
	Monotony	0	0	0	0
	Eye Strain	2	0	3	0
	Total Points	**7**	**25**	**8**	**25**
	% Conversion [B]	**11**	**14**	**11**	**14**
Special allowance (%)	Unavoidable delays	2	0	2	0
Total % allowance per processing step		13	14	13	14

[A] Points allocated as proposed by the International Labour Office of Switzerland (1992:491-49)
[B] Points conversion table supplied by the International Labour Office of Switzerland (1992:497-498)

D.3 Relaxation allowances for the packaging line at Le Cap Foods

Type of strain		**Processing steps in line 1**												
		11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**
Variable allowances (points [A])	**A. Physical Strain**													
	Average Force Exerted	20	18	20	0	0	0	0	0	3	0	10	10	10
	Posture	6	4	6	0	2	2	2	2	0	2	6	6	6
	Restrictive Clothing	0	0	0	0	1	1	1	0	0	0	0	0	
	B. Mental Strain													
	Concentration/ Anxiety	0	0	0	0	0	0	0	0	0	0	0	0	0
	Monotony	0	0	0	0	0	0	0	0	0	0	0	0	0
	Eye Strain	0	0	0	0	0	0	0	0	0	0	0	0	0
	C. Strain resulting from environment													
	Wetness	0	0	0	0	0	0	0	0	0	0	0	0	0
	Total Points	**26**	**22**	**26**	**0**	**3**	**3**	**3**	**2**	**3**	**2**	**16**	**16**	**16**
	% Conversion [B]	**14**	**13**	**14**	**10**	**10**	**10**	**10**	**10**	**10**	**10**	**12**	**12**	**12**
Special allowances (%)	Unavoidable delays	0	0	0	0	0	0	0	0	0	0	0	0	0
	Setup	0	0	0	0	0	0	0	1	1	0	0	0	0
	Tool allowance	0	0	0	0	0	0	1	0	1	0	0	0	0
Total % allowance per processing step		**14**	**13**	**14**	**10**	**10**	**10**	**11**	**11**	**12**	**10**	**12**	**12**	**12**

[A] Points allocated as proposed by the International Labour Office of Switzerland (1992:491-49)

[B] Points conversion table supplied by the International Labour Office of Switzerland (1992:497-498)

APPENDIX E VALUE CHAIN COST ANALYSIS

Results obtained from the value chain model for a 500 kg batch size of whole fish processed into 200 g fish mince pouches (15% HTVP) with added tomato sauce.

No.	Activities	ST [min.kg^{-1}]	No. employees	Total Kg processed/ station	Labour cost per activity [ZAR]	Material cost per activity [ZAR]	Total activity cost [ZAR}	Cumulative cost [ZAR]
1	Transport A- Storage to processing	0.02	2	500.00	4.98	-	4.98	4.98
2	Pre-cooker Rinser	0.07	1	500.00	11.47	-	11.47	16.45
3	Hot water dip	0.32	1	500.00	48.41	-	48.41	64.86
4	Pressurised Water spray	0.14	1	500.00	21.98	-	21.98	86.84
5	Evisceration	2.06	3	485.10	919.65	-	919.65	1 006.49
6.1	Cut fins & Fillet fish	3.76	4	305.67	1407.69	-	1 407.69	2 414.18
6.2	6mm Mincer	0.10	1	111.18	3.41	-	3.41	2 417.59
6.3	Transport B - mincer to Comitrol	0.06	2	111.18	3.96	-	3.96	2 421.55
6.4	Comitrol	0.47	2	111.18	31.91	-	31.91	2 453.46
6.5	Transport C - Comitrol to cold store	0.02	2	111.18	1.32	-	1.32	2 454.78
7.1	Skinning	0.31	1	222.86	21.02	-	21.02	2 475.80
7.2	Bowl cutter	0.43	1	190.67	25.03	-	25.03	2 500.83
7.3	Transport D - bowl cutter to cold store	0.06	2	190.67	6.79	-	6.79	2 507.62
8	Transport E - cold store to mixer	0.03	2	301.86	5.67	-	5.67	2 513.30
9	Mixing & Packaging	0.07	2	320.46	14.09	9 078.32	9 092.41	11 605.71
10	Transport F - packaging to cold store	0.04	2	320.46	7.93	-	7.93	11 613.64
11	Transport G: from storage to mixing	0.10	1	320.46	9.48	-	9.48	11 623.11
12	Weighing of materials,	0.23	2	327.49	45.47	170.26	215.73	11 838.84

	mixing, put in buckets							
13	Transport H: mixing to filling	0.01	1	327.49	0.67	-	0.67	11 839.51
14	Open pouch	1.03	2	327.49	207.19	2 260.28	2 467.48	14 306.99
15	Weigh fish in pouch	3.09	2	327.49	619.01	-	619.01	14 925.99
16	Weigh sauce in pouch	2.13	2	174.80	227.79	1 723.25	1 951.04	16 877.03
17	Clean pouch and transport to sealing station	1.48	2	502.29	454.19	-	454.19	17 331.22
18	Vacuum seal	0.91	1	502.29	139.57	-	139.57	17 470.79
19	Heat seal	1.14	1	502.29	176.08	-	176.08	17 646.87
20	Mark and place on retort trolley	0.52	1	502.29	80.66	-	80.66	17 727.53
21	Transport I: packaging to retort	0.03	1	502.29	4.37	-	4.37	17 731.90
22	Fill retort	0.05	1	502.29	8.31	-	8.31	17 740.22
23	Take out of retort	0.05	1	502.29	7.19	-	7.19	17 747.41
Total					**R 4 515.28**	**R 13 232.12**	**R 17 747.41**	